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Editorial

Technological Innovations and Data-Driven Support for Older Adults

Yun Jiang1*, RN, MS, PhD; Jinjiao Wang2*, RN, Mphil, PhD

1School of Nursing, University of Michigan, Ann Arbor, MI, United States
2School of Nursing, University of Rochester, Rochester, MI, United States
*all authors contributed equally

Corresponding Author:
Yun Jiang, RN, MS, PhD
School of Nursing
University of Michigan
400 North Ingalls Street
Ann Arbor, MI, 48109
United States
Phone: 1 734 7633705
Email: jiangyu@umich.edu

Abstract

Entering a new digital era where novel devices and emerging technologies, including artificial intelligence, are playing an incredible role with significant impact on health and health care delivery, JMIR Aging commits to supporting the community of patients and families, clinicians, and scientists to improve the efficiency, equity, and effectiveness of older adult care through the dissemination of cutting-edge evidence.

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KEYWORDS

technological innovation; JMIR Aging; older adults; innovation; technology; digital ageism; digital health; older adult care

One in every six people in the world will be aged 60 years or over in 2030, totaling 2.1 billion by 2050 [1]. As people age, they are more likely to experience complex health conditions that will need support from families, health systems, and society. To “add life to years” of older adults, one promising solution may lie in the appropriate use of technology. To date, technological innovations in health care, such as smart wearable devices [2], remote patient monitoring [3], socially assistive robots [4], augmented reality and virtual reality [5], automatic medication dispensers [6], and synchronized electronic health record systems that enable patients to virtually communicate with the care team [7], have been shown to help older adults stay physically active, live independently, monitor changes in medical conditions, and build social connections. More recently, advanced data science approaches have also been used to provide clinicians with point-of-care support for informed patient care decisions [8], speed up vaccine development [9], and support patients with shared decision-making [10].

Though the rise of technological and data science innovations brings promises, it also poses challenges. For example, many older adults, due to the lack of familiarity with technology, digital literacy, access to technological tools, or access to internet services, are negatively affected by the digital divide [11,12]. Digital ageism—the neglect of older adults’ needs, experience, and preferences in the user interaction design of some of the technologies—makes it even more difficult for them to engage in and enjoy the use of digital health technologies.

As an open-access journal, JMIR Aging strives to serve as a platform to support information-sharing and communications about older adults’ health and health care among clinicians, patients, caregivers, researchers, and policy makers. Our mission is to promote the use of technological innovations and data science to inform and improve health care services and health outcomes for older adults. Our focus includes digital health; emerging technologies; health informatics applications; patient education; and preventative care, clinical care, home care, and self-management support for older adults. JMIR Aging also covers aging-focused big data analytics using data from electronic health record systems, health insurance databases, federal reimbursement databases (eg, US Medicare and Medicaid), and other large data sets.

Founded in 2018, JMIR Aging has published 254 articles on various topics, such as the use of remote monitoring and artificial intelligence or robotic-driven systems [13], telehealth
visits among underserved older adult populations [14], and fall risk prevention mobile health solutions [15]. *JMIR Aging* has been indexed in PubMed, PubMed Central, DOAJ, Scopus, and the Emerging Sources Citation Index (Clarivate), and it is expected to receive an influential impact factor in 2023.

Entering a new digital era where novel devices and emerging technologies, including artificial intelligence, are playing an incredible role with significant impact on health and health care delivery, *JMIR Aging* commits to supporting the community of patients and families, clinicians, and scientists to improve the efficiency, equity, and effectiveness of older adult care through the dissemination of cutting-edge evidence.

### Conflicts of Interest
None declared.

### References


Feasibility, Safety, Enjoyment, and System Usability of Web-Based Aerobic Dance Exercise Program in Older Adults: Single-Arm Pilot Study

Kazuki Hyodo1, PhD; Tetsuhiro Kidokoro1,2, PhD; Daisuke Yamaguchi1, MA; Michitaka Iida3, MA; Yuya Watanabe1, PhD; Aiko Ueno1, MSc; Takayuki Noda1, BA; Kenji Kawahara1,4, BSc; Sumiyo Nishida1, BA; Yuko Kai1, PhD; Takashi Arao1, PhD

1Physical Fitness Research Institute, Meiji Yasuda Life Foundation of Health and Welfare, Tokyo, Japan
2Faculty of Sport Science, Nippon Sport Science University, Tokyo, Japan
3Information Services International-Dentsu Ltd, Tokyo, Japan
4Meiji Yasuda Health Promotion Center, Meiji Yasuda Health Development Foundation, Tokyo, Japan

Corresponding Author:
Kazuki Hyodo, PhD
Physical Fitness Research Institute
Meiji Yasuda Life Foundation of Health and Welfare
Tobuki 150, Hachioji
Tokyo, 192-0001
Japan
Phone: 81 42 691 1163
Email: k-hyodo@my-zaidan.or.jp

Abstract

Background: During the COVID-19 epidemic, opportunities for social interaction and physical activity among older people are decreasing, which may have a negative impact on their health. As a solution, a web-based group exercise program provided through a videoconferencing platform would be useful. As a web-based exercise program that older adults can easily, safely, and enjoyably perform at home, we developed a short-duration, light-intensity aerobic dance exercise program. Before studying the effectiveness of this exercise program, its characteristics, such as feasibility, safety, enjoyment, and system usability, should be examined among older adults.

Objective: This pilot study aimed to examine the feasibility, safety, and enjoyment of a web-based aerobic dance exercise program and the usability of a web-based exercise delivery system using a videoconferencing platform for older adults.

Methods: This study was designed as a prospective single-arm pilot study. A total of 16 older adults participated in an 8-week web-based aerobic dance program held every morning (8:30 AM to 8:50 AM) on weekdays at home. Retention and adherence rates were measured for the program’s feasibility. Safety was assessed by the heart rate reserve, an index of exercise intensity calculated from heart rate, and the number of adverse events during exercise sessions. Enjoyment of this exercise program was assessed by an 11-point Likert scale ranging from 0 (not enjoyable at all) to 10 (extremely enjoyable) obtained through telephone interviews after the first-, third-, sixth-, and eighth-week intervention. For usability, the ease of the videoconferencing platform system was assessed through telephone interviews after the intervention.

Results: A female participant with hypertension dropped out in the second week because of the continuously reported high blood pressure (≥180 mmHg) before attending the exercise session in the first week. Therefore, the retention rate was 93.8% (15/16). Among the remaining participants, the median (IQR) overall adherence rate was 97.4% (94.7-100). Regarding safety, the mean (SD) heart rate reserve during the aerobic dance exercise was 29.8% (6.8%), showing that the exercise was relatively safe with very light to light intensity. There were no adverse events during the exercise session. The enjoyment score (0-10 points) significantly increased from the first (6.7 [1.7]) to sixth (8.2 [1.3]) and eighth week (8.5 [1.3]). Regarding usability, 11 participants reported difficulties at the beginning, such as basic touch panel operations and the use of unfamiliar applications; however, all got accustomed to it and subsequently reported no difficulty.
Conclusions: This study showed high feasibility, enjoyment, and safety of the web-based aerobic dance exercise program in older adults, and the web-based exercise delivery system may have areas for improvement, albeit without serious problems. Our web-based aerobic dance exercise program may contribute to an increase in physical and social activities among older adults.

KEYWORDS
low-intensity exercise; home exercise; online exercise; supervised exercise; elderly; COVID-19; smartphone; tablet; videoconferencing platform

Introduction

Previous studies have reported that physical activity and social interaction positively influence the physical, cognitive, and mental health of older adults [1-4]. However, for some, access to places for exercise and social participation is difficult due to environmental limitations (such as limited transportation, low walkability, and remote location) as well as physical limitations and social factors [5,6]. During the initial period of COVID-19, the existing barriers were exacerbated because of political countermeasures to stay home and the closure of public sports and recreational facilities [7,8]. Although several restrictions have been eased, COVID-19 is ongoing, and some older people have not restarted physical activity [8]. Therefore, opportunities to participate in physical and social activities at home are crucial.

To address these issues, a solution could be a web-based exercise program at home [9,10]. With the development of communication technology, people can participate in group exercises at home with guidance from an instructor through videoconferencing platforms such as the Zoom application (Zoom Video Communications) [11,12]. Although a web-based exercise through videoconferencing platform is beneficial, the feasibility, safety, and enjoyment of the web-based exercise program and ease of use of a web-based exercise delivery system should be carefully considered especially in older adults [13]. Feasibility can be assessed using the individuals’ retention and adherence rates. As a program for older adults, safety is important because participants exercise at home without receiving on-site support from an instructor or supervisor. To mitigate the risk of adverse events during the web-based exercise program, light intensity and short duration of exercises are preferred. Additionally, to ensure its wide acceptance and long-term use, it should be easy to implement and enjoyable [14]. Regarding the system’s usability, its operations should be simple and easy for older adults because technical issues are the main barriers to using information and communication technology (ICT) devices [9,15].

Then, we have focused on a short-duration (20 minutes) and light-intensity aerobic dance exercise program considering these conditions. Dance is widely accepted as a group exercise for light-intensity aerobic dance exercise program considering these conditions. We developed a light-intensity aerobic dance program mainly comprising upper limb and trunk movements and confirmed that it was enjoyable for the older adults to perform, and it transiently enhanced cognitive function and mood in a laboratory setting [17,18]. Moreover, to deliver the web-based exercise program, we focused on the Zoom videoconferencing application on a tablet device because it is free and widely used in society, and recent studies reported no major problems with its usability among older adults [13,19,20]. Although several studies have examined the feasibility and effectiveness of web-based exercise programs using strength training, aerobic exercise, and yoga [13,19,20], to the best of our knowledge, no prior study has investigated this kind of short-duration and light-intensity web-based aerobic dance exercise program among older adults.

Therefore, before assessing its effectiveness, as a pilot study, we conducted a single-arm intervention to examine the feasibility, safety, and enjoyment of the web-based aerobic dance exercise program, alongside the usability of the exercise delivery system among older adults.

Methods

Participants

The participants were recruited from community-dwelling older adults who belonged to the Hachioji medical consumer cooperative. This organization provides medical and nursing support during illness or frailty, and members range from those in good health to those with some form of illness. The staff of the cooperative distributed flyers about the study to community members, and 24 interested older adults (n=6, 25% male and n=18, 75% female) voluntarily participated in an information session where they were fully informed about its purpose and experimental procedures. After the session, 8 participants declined to participate (7 did not match the schedule and 1 was unable to exercise due to sciatica). Finally, 16 older adults (n=4, 25% male and n=12, 75% female) provided their written informed consent. The inclusion criteria were as follows: aged 65 years or older; living in Hachioji City, Tokyo; no restriction regarding exercise by a medical doctor because of a cardiovascular or orthopedic disease; and no diagnosis of mental illness, including dementia. Given this study’s exploratory nature, no power analysis was performed to determine the sample size. Table 1 shows the participants’ demographic data.
Table 1. Characteristics of the participants (N=16).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>77.6 (4.5)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>4 (25)</td>
</tr>
<tr>
<td>Female</td>
<td>12 (75)</td>
</tr>
<tr>
<td>Living alone, n (%)</td>
<td>7 (43.8)</td>
</tr>
<tr>
<td>Current working, n (%)</td>
<td>2 (12.5)</td>
</tr>
<tr>
<td>Social participation (a), n (%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>4 (25)</td>
</tr>
<tr>
<td>Yes</td>
<td>12 (75)</td>
</tr>
<tr>
<td>Physical activity or exercise (a), n (%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1 (6.3)</td>
</tr>
<tr>
<td>Yes</td>
<td>15 (93.8)</td>
</tr>
<tr>
<td>Clinical treatment (b), n (%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>6 (37.5)</td>
</tr>
<tr>
<td>Yes</td>
<td>10 (62.5)</td>
</tr>
<tr>
<td>Pain status (c), n (%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>5 (31.3)</td>
</tr>
<tr>
<td>Yes</td>
<td>11 (68.8)</td>
</tr>
<tr>
<td>Devices ownership, n (%)</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>6 (37.5)</td>
</tr>
<tr>
<td>Cell phone</td>
<td>4 (25)</td>
</tr>
<tr>
<td>Smartphone</td>
<td>13 (81.3)</td>
</tr>
<tr>
<td>Tablet</td>
<td>3 (18.8)</td>
</tr>
<tr>
<td>Purpose of internet use, n (%)</td>
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</tr>
<tr>
<td>Email</td>
<td>7 (43.8)</td>
</tr>
<tr>
<td>Messaging app</td>
<td>10 (62.5)</td>
</tr>
<tr>
<td>Information collection</td>
<td>12 (75)</td>
</tr>
<tr>
<td>Videoconference</td>
<td>1 (6.3)</td>
</tr>
<tr>
<td>Shopping</td>
<td>2 (12.5)</td>
</tr>
<tr>
<td>Online game</td>
<td>1 (6.3)</td>
</tr>
<tr>
<td>Audios or videos</td>
<td>8 (50)</td>
</tr>
</tbody>
</table>

\(a\)Classified as “yes” if participating at least once a month.
\(b\)Classified as “yes” if receiving any treatment.
\(c\)Classified as “yes” if feeling any physical pain.

Ethics Approval
The ethics committee of the Physical Fitness Research Institute of Meiji Yasuda Life Foundation of Health and Welfare approved the study protocol (approval number: 2020-0001).

Procedures
The participants took part in an 8-week web-based aerobic dance exercise program through the videoconferencing platform using a tablet device at home. Before starting the intervention, we lent 4 electronic devices to every participant free of charge for accessing the exercise program and monitoring their heart rate (HR) during exercise, as follows: (1) tablet (iPad [Apple Inc]) for web-based exercise, (2) HR monitoring device (OH1 [Polar Electro Oy]), (3) smartphone (iPhone SE2 [Apple Inc]) for HR measurement, and (4) Wi-Fi router (Pocket WiFi 801ZT [Softbank]) with a maximum downstream speed of 112.5 Mbps and a maximum upstream speed of 37.5 Mbps for data transmission. As the recommended bandwidth for group video calling on Zoom is 3.8 Mbps/3.0 Mbps (up/down), we prepared
the Wi-Fi router that met these requirements. We paid for the data communication fees used in this study. Before lending these devices, we installed LINE WORKS (WORKS MOBILE Corp) and Zoom on the iPad and the HR monitoring app on the iPhone for each participant. LINE WORKS is a messaging app that includes group chat, calling, and survey functions. We used it to send the participants the Zoom URL and check their health condition through a simple checklist on the app.

During the exercise session, the HR of each participant was measured with the monitoring device and tracked on the screen at the laboratory in real time by the research staff. Moreover, participants’ subjective feelings regarding enjoyment of the exercise program were obtained through telephone interviews at the end of the first, third, sixth, and eighth weeks of the intervention. Figure 1 shows the participants exercising at home using the devices.

**Figure 1.** Participant exercising at home. Participants exercised following the guidance of the instructor via tablet. All the devices were set up by the research staff.

### Exercise Program

The total duration of the web-based exercise program was 20 minutes, comprising a 5-minute warm-up (stretching), a 10-minute light-intensity aerobic dance exercise called Slow Aerobic Dance Exercise (SADE), and a 5-minute cooldown (stretching). The details of the SADE have been reported in a previous study [11]. Briefly, it included 3 upper-body dynamic movements (twisting the upper body, pulling back the elbows, and clapping hands while shaking the waist from side to side, and waving arms like wiping the windows while shaking the waist from side to side). All movements were performed to music with a tempo of 90-120 beats per minute (bpm) because we confirmed that older adults can comfortably practice the aerobic dance program at 90-120 bpm [17,18]. Additionally, the movements were slightly changed every 2 weeks to avoid boredom. Moreover, 1 of the 3 female professional aerobic exercise instructors led the exercise program using Zoom. The exercise started at 8:30 AM, from Monday to Friday, for 8 weeks without national holidays (February 1 to March 27, 2021). In total, 37 sessions were conducted during the intervention period.

### Web-Based Exercise Delivery System

We used Zoom as the videoconferencing platform to deliver the web-based exercise program to the participants. On the morning of the exercise day, the Zoom URL was sent to the participants through LINE WORKS. The participants only needed to access the LINE WORKS application and click on the Zoom URL to participate in the web-based exercise session.

### Safety Management

To monitor and manage participants’ safety during the exercise, we obtained information on their health conditions using a simple checklist on LINE WORKS every morning before the session. Moreover, we monitored their movements and HR during the exercise. The simple health checklist included the following three questions: (1) “How is your overall health condition today?” (Excellent/Good/Poor), (2) “What is your systolic (SBP) and diastolic (DBP) blood pressure before the session?” (SBP: less than 140 mmHg/140-179 mmHg/180 mmHg or higher; DBP: less than 90 mmHg/90-109 mmHg/110 mmHg or higher), and (3) “Did you attend the session today?”
Every participant had to measure their resting blood pressure before starting the session at home using an automatic sphygmomanometer provided by the research team. Before the session, the research staff members checked their answers. Regarding the overall health condition, if any participant answered “Poor” on the day of the session, a research staff called them to check how they were feeling and whether they could safely participate. Regarding blood pressure, based on the report of the Ministry of Health, Labor, and Welfare [21], an individual with an SBP of 180 mmHg or higher or DBP of 110 mmHg or higher was suggested not to participate in the exercise on the day for safety reasons. Additionally, in case of adverse events (eg, falls, injuries, or cardiovascular events) during the intervention, we were prepared to call the participant, a relative living with the participant, or someone who lived nearby to check on their situation and to call an ambulance in case of an emergency.

An overview of the web-based HR monitoring system is shown in Multimedia Appendix 1. Every participant was asked to wear the HR monitor on their upper arm before the exercise began. Each participant’s HR was displayed on the iPhone app through Bluetooth, and the HR information was transmitted to a web application on a PC at the laboratory using the internet in real time. Using this system, we monitored the HR and heart rate reserve (HRR) of each participant during the exercise. Before starting the session, we checked if the HR was displayed correctly on the web application. If someone’s HR was not displayed due to Bluetooth, Wi-Fi, or other issues, the participant called the research staff, or we called them to solve the problem. The HRR of each participant was calculated using the following equation:

\[ \text{HRR} \% = \frac{(\text{HR during exercise} - \text{resting HR})}{(\text{predicted maximum HR} - \text{resting HR})} \times 100 \]

The predicted maximum HR was calculated using the following equation [22]: 208 − 0.7 × age. The resting HR was measured during a visit to the participants’ homes to install apps and set up the devices. Each participant managed to exercise at an intensity of less than 60% of their HRR throughout the exercise because exercise above 60% HRR is defined as high intensity according to the American College of Sports Medicine [23], and the risk of cardiovascular events may be higher [24]. If the HRR of the participant remained over 60% for a few minutes, the research staff called them to confirm whether the exercise intensity was appropriate, advising them to slow down the exercise movement according to the situation. Along with monitoring the HR, we checked whether the participants were exercising safely and correctly. Figure 2 shows the monitoring screens of each participant’s movement during the session.

Figure 2. All participants shown on a monitor screen in the laboratory. The research staff checked the movements of the participants on the screen for safety during the exercise session.

Measures

Feasibility

The retention rate was calculated as the proportion (expressed as a percentage) of the number of participants who completed the 8-week assessment to the total number. The adherence rate was calculated individually as the percentage of the sessions attended to the total number (37 sessions) throughout the intervention period, and the average adherence rate was obtained.

Safety

Safety was examined in terms of the intensity of the exercise program and the number of adverse events. The exercise intensity was measured using the average HR and HRR during SADIE across all sessions for each participant. An adverse event was defined as any unfavorable health-related events such as falls, injuries, or cardiovascular events that occurred during the exercise intervention.

Enjoyment

Regarding enjoyment, the participants were asked to rate their subjective enjoyment on a scale at the end of weeks 1, 3, 6, and 8 of the intervention during telephone interviews. Enjoyment was assessed by a single question, “How do you feel about the exercises?”. Participants were asked to rate them on an 11-point Likert scale ranging from 0 (not enjoyable at all) to 10 (extremely enjoyable).

Usability of the Web-Based Delivery System

The usability of the system was evaluated from the participants’ perceived experiences with using the devices providing a web-based exercise program and monitoring HR (tablet, OH1, smartphone, and Wi-Fi router). They were asked to provide their perceived experiences using the devices over the phone.
by research staff. Telephone interviews were conducted after the last session of the intervention using a single question, “What do you think about your experiences with using the system for delivering web-based exercises?”. For the usability assessment, the interviewer recorded the participants’ comments and extracted the main ones. The participants were classified into the following 3 categories owing to their comments based on the discussions among all the coauthors: (1) category A: those who reported no problems with using the system throughout the intervention period; (2) category B: those who reported some challenges at the beginning but gradually got used to it or could use it without support by the end of the intervention; and (3) category C: those who reported difficulty or unfamiliarity throughout the intervention period.

**Statistical Analysis**

The participants’ adherence rates to the session, as well as HR and HRR during the exercise, were reported as mean (SD) or median (IQR) whenever they comprised either a normal or nonnormal distribution, respectively. To obtain the enjoyment score, a repeated measure ANOVA was conducted to examine the change in the enjoyment of the exercise program during the intervention period (weeks 1, 3, 6, and 8). If a significant difference was observed in the ANOVA, the post hoc multiple comparisons with Bonferroni correction were performed. For the assessment of the system’s usability, 3 categories were tested using the chi-square test for goodness of fit. Furthermore, Cohen’s $d$ effect size was calculated to assess the change in outcome measure in response to the intervention, while $\eta^2$ was computed as a measurement of the effect size for ANOVA. A significant level was set at 0.05 for all analyses. We employed R version 4.1 (R Foundation for Statistical Computing) [25] for the data analysis.

**Results**

**Feasibility: Retention and Adherence**

One female participant with hypertension continuously reported high SBP ($\geq$180 mmHg) before attending the exercise since the first session. Based on the safety concerns, in the second week, we suggested that she consult a family doctor and withdraw from this study. Therefore, 15 participants completed the 8-week intervention, resulting in a retention rate of 93.8%. For the analysis of adherence, data from the remaining participants ($n=4$, 27% male and $n=11$, 73% female) were used. The median (IQR) adherence rate was 97.4% (94.7-100).

**Safety**

Based on 15 participants, the mean (SD) overall HR and HRR during the SADE were 93.4 (5.7) bpm and 29.8% (6.8%), respectively, indicating the SADE was light intensity for the participants [26]. No adverse event was reported during the exercise session throughout the entire intervention period.

**Enjoyment**

The mean (SD) enjoyment scores of the exercise program at weeks 1, 3, 6, and 8 were 6.7 (1.7), 7.5 (1.4), 8.2 (1.3), and 8.5 (1.3), respectively. The repeated measures ANOVA revealed a significant difference among the weeks—$F_{1,98}=27.73$, $P=0.002$, $\eta^2=0.35$. Post hoc analysis with Bonferroni correction showed that enjoyment scores at weeks 6 and 8 were significantly higher than at week 1—$t_{1,98}=-3.14$, $P=0.04$, $d=-0.81$; $t_{1,98}=-3.81$, $P=0.001$, $d=-0.98$, respectively.

**System Usability**

The results from the telephone interview to assess the system usability of the web-based exercise showed that 4 (27%) participants had no problems (category A), 11 (73%) had some challenges at the beginning but got used to it or were able to use it without support at the end of the intervention (category B), and none reported any difficulties or unfamiliarity in use throughout the entire intervention period (category C). The chi-square test for goodness of fit showed significant differences between category B and category A or C.

**Discussion**

**Principal Findings**

A single-arm pilot study was conducted to evaluate the feasibility, enjoyment, and safety of the web-based aerobic dance exercise program and the usability of the web-based system for providing the exercise program for older adults. In this study, the following findings were obtained: (1) regarding feasibility, the retention rate and average adherence rate were high; (2) regarding safety, the average HRR during the SADE was within the range of light-intensity exercise, and there were no adverse events during the sessions; (3) regarding enjoyment, the score for the exercise program increased gradually until the end of the intervention period; and (4) regarding system usability, about a third of the participants faced some challenges in using this system at the beginning, but all got to use it at the end. These results suggest that our web-based aerobic dance program is highly feasible, enjoyable, and safe for older adults, with some areas that could be improved in the web-based exercise delivery system.

**Comparison With Previous Research**

A recent systematic review based on 22 selected papers reported the process characteristics of technology-based exercise intervention programs [27]. It highlighted that there were marked differences in the attrition (0%-36%) and adherence rates (67.78%-100%) for a technology-based group training exercise program for older adults. The authors suggested that the differences in these variables were because of the varying intervention characteristics, such as implementation time; frequency; duration; intensity; mode of exercise program, including interactive or noninteractive communication, individual or group, with or without a supervisor; technology-based delivery system component, such as commercially available or customized technology systems; and participants’ characteristics, such as living independently or institutionalized. In this study, the participants showed high retention rates (15/16, 93.8% participants) and adherence rates (36/37, 97.4% sessions) to the web-based exercise program, which is consistent with the results of a previous study that used the similar intervention characteristics, such as intervention period, sample age, living status, home setting, and session duration. Schoene et al [28] reported a retention rate of 83.3%...
(15/18) and an adherence rate of 100% for an unsupervised, home-based, 15- to 20-minute dance step exercise program using a video game. Daly et al. [29] suggested that an exercise program was feasible if the retention rate was higher than 90% and the average overall adherence rate was higher than 75%. Considering this, our exercise program was highly feasible for older adults. This seems to be related to the characteristics of the exercise, including an aerobic dance with light intensity and short session time. Dance exercise is widely accepted as a group exercise for older adults in Western countries [16]. This exercise type also seems to be acceptable for Japanese older adults. Moreover, even though the frequency (5 days/week) of our exercise program was higher than that (3 days/week) in the study by Schoene et al. [28], the retention rate was a little higher. This might be because the participants were supervised using a videoconferencing platform during the session by the instructor, and they conducted the session at the same time every morning on weekdays. Kim et al. [30] reported high feasibility (100% in retention and adherence rates) of their exercise intervention using Tai Chi and yoga programs, with 60 minutes per session, 3 days per week, for 8 weeks. However, they conducted the intervention using a motion capture sensor and virtual reality avatar to provide real-time visual feedback of the movement at the university research laboratory, which would not be practical as a home-based intervention program.

In a previous systematic review, Valenzuela et al. [27] showed that the reasons for dropouts from their technology-based exercise intervention included low motivation, loss of interest, arthritic discomfort, lack of time, inability to travel to the session, limited space at home to set up the system, inability to use the technology, and being ashamed of playing computer games. Considering these reasons, the high feasibility of our exercise program might be because of the high level of enjoyment and safety. The participants showed a relatively high enjoyment score at the end of the first intervention week, and thereafter, there was a gradual increase during the intervention period. These results showed that the exercise program was enjoyable for the participants throughout the period. This seems to be partly because of the adaptation of the exercise program to each participant’s skill and ability. This might have reduced their state of boredom and increased their motivation. Additionally, our exercise program was constructed with light intensity and simple movements, which are favorable for older adults [31]. These conditions might have motivated the participants to engage in the exercise session every morning throughout the intervention period. This was also supported by the participants’ feedback through telephone interview after the intervention. Many participants commented that the instructors were very professional and friendly, making it easy to follow the aerobic dance program. Furthermore, they reported that the movements of the aerobic dance were not too difficult, and they could catch up even if they skipped or missed the sessions. They also experienced feeling refreshed after the exercise, which made them want to continue the program.

Regarding safety, we examined exercise intensity during the SADE using the HRR and the number of adverse events. The average HR and HRR during the exercise had a mean of 93.4 (SD 5.7) bpm and a mean of 29.8% (SD 6.8%), respectively. The average HRR ranged from very light to light intensity according to the American College of Sports Medicine guideline [26], showing that the exercise intensity was relatively safe. Regarding adverse events, any adverse events during the exercise session, such as cardiovascular events, falls, or injuries, did not occur. Among the previous technology-based exercise intervention studies, there were a few cases of knee and calf pain during strength training [29] and a fall during an exergame intervention using a balance board [32]. Since the aerobic dance exercise in this study mainly comprised upper body movements and was not physically demanding, it is considered that the risk of falls was low and joint and muscle pain did not occur.

From a safety management perspective, it should be mentioned that 1 participant with hypertension repeatedly reported high SBP (≥180 mmHg) before attending the exercise session since the first session. Although the causal relationship between the intervention and reported high SBP is unclear, it is possible that the anxiety to participate in the web-based exercise session elicits psychological stress, and this consequently causes high SBP. This case suggests the importance of management of blood pressure before attending the web-based exercise session to reduce the risk of exercise-related adverse events.

Another important condition of a web-based exercise program for older adults is the system’s usability. We examined this condition through telephone interviews at the end of the intervention. Since nobody reported any difficulties or unfamiliarity in using the system at the end of the intervention, there could be no serious problems with its usability. This is partly consistent with the previous study reporting that the operation of Zoom for participating in web-based exercise classes was easy for older adults [13]. However, about a third of the participants had some challenges using it at the beginning, suggesting that there could be usability improvements. According to the participants’ comments, a difficult point was the touch panel operations of smartphones or tablets, such as tapping, scrolling, and swiping. Some participants also commented that when operating unfamiliar apps, such as Zoom and LINE WORKS, it was difficult to know what to do next when unfamiliar screens appeared due to unusual operations.

Although many had smartphones or tablet devices, most of them had never used the lent devices or apps, and it could take them some time to get used to them. For further improvement in usability, it may be necessary to make the operation of devices easier and older-adults–friendly, such as by reducing the number of taps to participate in the web-based exercise and providing detailed instructions on how to use devices and apps [33].

Moreover, it should be considered that the high rate of smartphone or tablet ownership among participants (87%) may have contributed to ensuring no significant usability issues. According to a recent national survey on the use of communication devices, the rate of internet users was 73.4% among 60-year-old people and 40.8% among those aged ≥70 years in Japan [34]. Therefore, older adults unfamiliar with ICT may have some problems using this web-based exercise delivery system. Although the number of internet users in the older population has been rapidly increasing in Japan [35], further examination of usability among older adults with low ICT literacy is needed.
Limitations and Future Directions

In this study, there are several limitations and, hence, further research is required. First, participants’ characteristics could influence the results. The participants were volunteers, and many belonged to the community organizations as leaders. Therefore, they could have been highly motivated to participate in the intervention program, which may have influenced their adherence rate and enjoyment. Moreover, many participants owned smartphones or tablets, which may have contributed to the results of the system’s usability. Further studies with a larger sample size are needed to examine whether similar results can be obtained with older adults who are physically and socially inactive or are unfamiliar with using ICT devices. Second, to strictly examine the safety of the exercise program, we used a smartphone and HR monitor to check the exercise intensity, and asked research staff to monitor participants’ health condition and movements during the exercise session. However, from a cost-effectiveness standpoint, the system needs to be simplified for implementation in the real world. Finally, since this is a single-arm pilot study, the effectiveness of the exercise program is unknown. A future study on the effect of this web-based exercise program on physical, mental, and cognitive function in older adults should be conducted using a randomized controlled design.

Conclusions

This pilot study indicates that an 8-week intervention using a web-based aerobic dance program with short duration (20 minutes), high frequency (5 days per week), and light intensity (HRR 29.8%) is feasible, safe, and enjoyable for older adults. Moreover, although there were no serious issues with the web-based exercise delivery system using a videoconferencing platform, some areas for improvement were found. These results suggest that our web-based exercise program could be valuable in enabling healthy behaviors for older adults. Future studies on the generalizability of the results and effectiveness of this web-based aerobic dance exercise program and usability improvements for real-world implementation are needed.

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Data Availability

The data that support the findings of this study are available from the corresponding author (KH) upon reasonable request.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Overview of the heart rate (HR) online monitoring system. Participants’ HR was measured by an OH1 HR monitor on their arm, and the data were sent to the smartphone app via Bluetooth. The participants could see their HR on the smartphone app. Moreover, the HR data were sent to the web application via the internet, and the research staff could check the HR of all participants in one screen. Once the name of a participant was clicked, the time series data on their individual HR would be displayed.

References


Abbreviations

- bpm: beats per minute
- DBP: diastolic blood pressure
- HR: heart rate
- HRR: heart rate reserve
- ICT: information and communication technology
- SADE: Slow Aerobic Dance Exercise
- SBP: systolic blood pressure

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Exploring the Potential of Technology to Promote Exercise Snacking for Older Adults Who Are Prefrail in the Home Setting: User-Centered Design Study

Katarzyna Stawarz¹, PhD; Ian Ju Liang², MSc; Lyndsay Alexander³, PhD; Angela Carlin⁴, PhD; Anjana Wijekoon⁵, PhD; Max J Western², PhD

¹School of Computer Science and Informatics, Cardiff University, Cardiff, United Kingdom
²Department for Health, University of Bath, Bath, United Kingdom
³School of Health Sciences, Robert Gordon University Aberdeen, Aberdeen, United Kingdom
⁴Centre for Exercise Medicine, Physical Activity and Health, Sports and Exercise Sciences Research Institute, University of Ulster, Newtownabbey, United Kingdom
⁵School of Computing, Robert Gordon University Aberdeen, Aberdeen, United Kingdom

Corresponding Author:
Katarzyna Stawarz, PhD
School of Computer Science and Informatics
Cardiff University
Abacws
Senghennydd Road
Cardiff, CF24 4AG
United Kingdom
Phone: 44 029 2251 0037
Email: stawarzk@cardiff.ac.uk

Abstract

Background: Older adults are at increased risk of falls, injury, and hospitalization. Maintaining or increasing participation in physical activity during older age can prevent some of the age-related declines in physical functioning that contribute to loss of independence and low reported quality of life. Exercise snacking may overcome some commonly cited barriers to exercise and encourage older adults to engage in muscle strength and balance activity, but the best way to deliver and support this novel format remains unknown.

Objective: Our aim was to explore how the novel exercise snacking approach, that is, incorporating short bouts of strength and balance activities into everyday routines, could be supported by technology within a home setting and what types of technologies would be acceptable for older adults who are prefrail.

Methods: Following a user-centered design process, 2 design workshops (study 1) were conducted first to understand older adults’ (n=11; aged 69-89 years) attitudes toward technology aimed at supporting exercise snacking at home and to inform the design of 2 prototypes. Next, based on the findings of study 1, an exploratory pilot study (study 2) was conducted over 1 day with 2 prototypes (n=5; aged 69-80 years) at the participants’ homes. Participants were interviewed over the telephone afterward about their experience. Transcripts were analyzed using framework analysis.

Results: The results showed that the participants were positive toward using technology at home to support exercise snacking, but both exercises and technology would need to be simple and match the participants’ everyday routines. Workshop discussions (study 1) led to the design of 2 prototypes using a pressure mat to support resistance and balance exercises. The exploratory pilot study (study 2) participants reported the potential in using smart devices to support exercise snacking, but the design of the initial prototypes influenced the participants’ attitudes toward them. It also hampered the acceptability of these initial versions and highlighted the challenges in fitting exercise snacking into everyday life.

Conclusions: Older adults were positive about using technology in their homes to support strength and balance exercise snacking. However, although promising, the initial prototypes require further refinement and optimization before feasibility, acceptability, and efficacy testing. Technologies to support exercise snacking need to be adaptable and personalized to individuals, to ensure that users are snacking on balance and strengthening exercises that are appropriate for them.
Introduction

Background
The benefits of physical activity (PA) across the life span are well documented [1]. Within the United Kingdom, older adults (aged ≥65 years) should accumulate 150 minutes per week of moderate-intensity aerobic activity [2]. Furthermore, the guidelines highlight that any level of PA should be encouraged, and activities to improve or maintain muscle strength and flexibility should be incorporated at least 2 days per week [2]. However, many older adults are failing to meet these guidelines and report low levels of muscle and bone strengthening activities [3]. Older adults are at increased risk of falls and injury owing to age-related declines in physiological functioning [4], which can impede their quality of life and independence and place an enormous strain on health and social care costs at the societal level [5].

Recent studies have also indicated that older adults spend a high proportion of their day engaged in sedentary behaviors [6], that is, any waking activity in a sitting, lying, or reclining posture where energy expenditure is <1.5 metabolic equivalents [7]. As the proportion of older adults in our society increases [8], strategies to promote PA and reduce sedentary behavior in this age group are important to maintain physical functioning [9] and improve health-related quality of life [10].

To promote and sustain participation in strength and balance exercise as individuals age, there is a need to develop interventions for this population that are effective, inclusive, acceptable, and safe [11]. Furthermore, interventions should enable older adults to overcome some of the commonly cited barriers to current participation in PA. Such barriers include dislike for activities that are structured or sport based, time commitments, and limited access to facilities [12-14]. Integration of functional exercise into daily routines may provide another alternative to PA promotion in this population and overcome the recognized barriers in relation to structured exercise programs [15].

Incorporating short bouts of exercise across the day or exercise snacking [16] represents an innovative approach to PA promotion among older adults. It is similar to Snacktivity [17,18], which is mostly used in the context of aerobic PA. Both promote opportunities to engage in exercises that are safe and compatible with individuals’ surroundings and lifestyle [16]. So far, exercise snacking has been shown to be an accessible, acceptable, and effective alternative to traditional exercise in older adults [16,19].

Technology has the potential to support PA at home. Recent studies have focused on wearables and activity trackers such as Fitbit [20], which can be effective in encouraging PA and reducing sedentary behaviors [21]. However, these devices tend to focus on supervising or monitoring older adults and tend to support a limited number of activities, especially cardiovascular activities such as walking [20]. Given their reliance on measuring steps and location, they are unsuitable for supporting strength and balance exercises. Similarly, previous studies on supporting older adults’ exercise at home have focused on more complex solutions such as Kinect [22] or social robots to support (predominantly aerobic) PA [23]. These solutions are expensive and require planning to fit the exercise sessions into one’s day. Owing to the situated nature of exercise snacking and its links with everyday routines, Internet of Things (IoT) devices are well suited to provide technological support. IoT devices can be easily embedded at home and provide both monitoring and guidance, such as reducing office workers’ sedentary behavior [24], supporting good posture while sitting [25], or exercising [26]. As such, they could be used to support exercise snacking at home as part of routine everyday activities.

Objectives
This project explored how ubiquitous technology could be embedded in the home setting to support community-dwelling older adults who are prefrail with exercise snacking activities to improve strength and balance. It builds on previous studies that have demonstrated exercise snacking to be as effective as resistance training in improving muscle functioning [16] but has the added benefit of overcoming barriers to engagement in PA for older adults.

The main objective was to develop and test a set of interactive prototypes that could be embedded in the home environment to support strength and balance exercises. To do so, we engaged older adults who are prefrail in the design of the prototypes and conducted an exploratory home evaluation. Health technologies tend to be designed without consideration of older adults’ perspectives about PA [27], which can reduce their usability or adoption within this user group. Therefore, our goal was to work directly with older adults and use their input and ideas as a starting point to ensure that the prototypes addressed their needs.

Methods

Approach
This project followed an iterative, user-centered design (UCD) process [28] to identify the requirements for initial prototypes and explore their potential; however, we did keep in mind the principles of person-based approach [29], as this work will be used as a starting point for the development of a future behavior change intervention. Study 1 (design workshops) aimed to identify appropriate exercises that older adults are willing to do at home and attitudes and preferences toward technologies that might support PA. Study 2 (home evaluation) then developed and piloted new prototype technology informed by the results of study 1.

Participants and Recruitment
We recruited 16 community-dwelling older adults who are prefrail from participants of a randomized controlled trial...
(focused on encouraging PA among older adults [30]) who consented to be approached for future research projects. Of the 16 individuals, 11 (69%) participated in study 1 (mean age 74, SD 5.5; range 69-89 years). Of the 11 participants, 7 (64%) were women and all (n=11, 100%) were White British. A further 5 participants participated in study 2 (mean age 74, SD 4.87; range 69-80 years), and 3 (60%) of them were women. Participants who responded to the study email advertisements were sent a participant information sheet describing the study.

**Study 1—Design Workshops**

**Materials**

Study 1 involved two 2-hour design workshops in Bristol, the United Kingdom. To facilitate discussions, participants were provided with handouts showing examples of specific muscle strengthening and balance exercises and simple Tai Chi movements they could do at home, which were also demonstrated to participants by a trained exercise instructor (IJL). A set of electronic components (eg, proximity sensors, pressure mats, vibrating components, and lights), examples of wearable devices (eg, a smartwatch and an activity tracker), and an Amazon Alexa were used to facilitate the discussions about technology supporting exercise snacking at home.

**Procedures**

Workshops were conducted on the same day in February 2020 within a Sensor Platform for Healthcare in a Residential Environment (SPHERE) smart home [31]. The smart home belongs to the University of Bristol and is a terraced house with several rooms equipped with various sensors such as movement sensors and near-field communication (NFC) tags. The sensors were visible throughout the home; however, they were not used as part of this study. Nevertheless, participants were able to see how smart technologies could be implemented in a home environment, which facilitated discussions about how new devices could fit into their existing homes.

Each session started by discussing the participants’ current PA levels, including home-based and group activities and any barriers to exercise that they had encountered. Exercise snacking and exercise handouts (preferred format and content) were then discussed. A researcher and trained exercise instructor demonstrated 5 exercise snacking and 5 Tai Chi snacking movements [19], with participants trying each. This session was conducted in a living room, and participants were able to use chairs and a sofa as part of the exercises. Participants then discussed their thoughts about the exercises and how they could be fit into their daily routines and home environments.

Participants then moved through the house (kitchen, bathroom, bedroom, and dining room), discussing suitable exercises for each room, how rooms differed from their own environment, and how that difference could affect the exercise. In addition, any technology that could support and prompt exercise was discussed. This was facilitated by a member of the research team. Subsequently, 1 researcher presented examples of various technologies and sensors, explaining how each item worked and how it could be used in practice. Participants then discussed which components and devices could be useful to support exercise snacking in their home environment.

After the study, participants received a shopping voucher worth £10 (US $12.91) for participating in the workshop.

**Study 2—Feasibility Evaluation With Semistructured Interviews**

**Materials**

On the basis of the key findings from study 1, a total of 2 types of interactive prototypes were built: 1 to support 1-legged balance exercises and 1 to support sit-to-stand exercises (Figure 1). These 2 activities were chosen because participants agreed that they were useful and were the easiest to be integrated into their everyday routines, that is, were easy to master and could be done anywhere at home. Each prototype consisted of a pressure mat and a companion screen. As their design was influenced by study-1 results, more details are provided in the Prototype Development section after study-1 results.

The prototypes were accompanied by a booklet explaining exercise snacking and the 2 selected exercises, with advice about how to do them correctly and suggestions of times and places at home where they could be done. The booklet also included a setup and troubleshooting guide.
Figure 1. Exercise snacking prototypes for supporting (A) 1-leg balance and (B) sit-to-stand exercises. Images were captured by the researchers to demonstrate potential locations for the prototypes.

Procedures
The evaluation study consisted of 2 parts (an exploratory home evaluation and an interview) and was conducted in Bath, the United Kingdom, between May 2021 and June 2021. Written informed consent was obtained from all participants. No personally identifying information was collected and the data were anonymized. Prototypes were delivered to participants’ homes by a researcher; participants also received written setup instructions, and the researcher was available via telephone to provide any further technical and exercise support. Owing to COVID-19 restrictions, the researcher followed a COVID-19–secure process, which involved contactless delivery and collection, with no entry into the participant’s home. Each participant received both prototypes (balance mat and sit-to-stand mat) and was requested to use them for a single day. They were asked to think about their everyday routines and place the prototypes and the feedback screen in spaces where they would be the most likely to see and use them without having to go to a dedicated room. After delivering the prototypes, the researcher explained each exercise to the participant over the telephone.

At the end of the day, a researcher collected the prototypes and, later, conducted the telephone interview. Interviews lasted approximately 30 to 45 minutes and covered participants’ general experience of setting up and using the prototypes, views about the utility of the technology going forward, and their general views about how to improve the prototypes or better integrate technology into their daily lives. After that, participants received a shopping voucher worth £30 (US $41.67) for testing the prototypes at home and participating in the phone interviews.

Ethics Approval
Both studies received favorable ethical opinion from the University of Bristol (project ID 99482) and Cardiff University (COMSC/Ethics/2020/071).

Data Analysis
Study-1 workshop discussions were audio recorded and transcribed verbatim for subsequent analysis. Any mention of participants’ names in the transcripts was replaced by participant numbers before the analysis. Transcripts were analyzed thematically [32] using both deductive and inductive approaches to explore insights related to the specific topics we focused on and any unexpected findings. Before analysis, transcripts were read to identify specific features for the prototypes, so that they could be incorporated by the developer while data analysis continued. One of the authors (IJL) coded all the transcripts. Codes were then reviewed and discussed by 2 other authors (KS and MW), who identified the provisional themes and drafted the results. The themes and draft findings were then reviewed and discussed with all authors until the final themes were fully defined.
Study 2 ended with semistructured telephone interviews, which were audio recorded and transcribed verbatim. Transcripts were anonymized. Framework analysis [33] was applied to the data, as the authors were interested in specific topics. Following familiarization and coding of the transcripts, one of the authors (AW) created a framework table using interview questions as categories (columns), and each participant was allocated a row, with codes in corresponding cells. Then, 2 authors (AW and KS) summarized the findings in each cell to identify potential themes. Provisional themes were drafted by 2 authors (KS and MW) and then discussed with all authors, leading to the strengthening of some themes and removal of others.

Results

Study 1—Workshops

Overview

We were interested in understanding participants’ views about and attitudes toward exercise, PA at home, and technology—these discussion topics formed the initial structure for resulting themes. Within each topic, themes and subthemes identified through the analysis are reported. They are summarized with representative quotes in Multimedia Appendix 1 and described in more detail in the following sections.

Topic 1—Attitudes Toward Exercise

Several themes were identified in relation to common barriers to participation. A common point of discussion centered around leisure settings being viewed as a nonwelcoming space for older adults. Several participants pointed to leisure centers and gyms as being young and male dominant, whereas others recognized that much of the provision for older adults was group based, with participants noting that they felt a lack of confidence in exercising with others. There were also barriers relating to individuals’ motivation to do regular exercise. This was linked to the fear of falling and injury or lack of baseline strength, which made exercise perceived risky prospect. However, despite these participation barriers, there was a strong sense that exercise was important to the participants, with many highlighting the health and well-being benefits it brings. Participants also recognized exercise to be a way of building confidence to stay engaged in other forms of social and leisure activity. Similarly, the social aspect of exercise itself was regarded as a key driver for participation, particularly for walking and aerobic activities.

Participants generally agreed that exercise should match the profile and ability of the target user and saw potential inexercise snacking to overcome this issue. For example, there were exercises that were much more suited to people in their later life, particularly owing to their physical capabilities, such as balance or sit-to-stand exercise. In this regard, the exercise snacking concept was viewed favorably, as it was seen to enable people to build up from different baselines and progress on their own terms and appeared to be easy to master as a set of exercises. In addition, it could help to overcome other barriers that participants had mentioned—including the ability to do PA in a low-risk environment that was not a leisure setting. Tai Chi movements, as a proposed format of exercise snacking, had more of a mixed reception, with preconceptions both acknowledging it as a useful, relaxing exercise but potentially tricky to learn.

Topic 2—Exercising in the Home Environment

The second topic explored how the home environment might support or hinder regular engagement in exercise snacking. While walking around the smart home environment, some participants commented about the impact of location and how different spaces lend themselves to exercise more than others. For example, it was apparent that the amount of floor space in a room was important for it to be seen as a space to exercise in. Another consideration was the need to work around other people at home, including partners, spouses, grandchildren, or pets. There was also a sense that certain rooms had a particular function that would preclude them from being a place for exercise, such as the dining room.

Much of the conversation about the suitability of spaces to exercise centered on safety in the home environment. Having solid objects to hold on and to support balance and stability where necessary was seen as an important consideration, with key examples in the more spacious rooms being kitchen worktops and chairs. In addition, for some formats of exercise, such as balancing, having soft furnishings and carpeted floors would make the environment feel safer than hard spaces.

A final theme related to the home environment was how certain spaces or everyday tasks could be used as opportunistic contextual cues to prompt exercise snacking. For example, the lounge was suggested as a good place to be prompted and do exercise, as it is typically the space where older adults would otherwise sit for long periods—as such, it would be suitable for exercises that can be done while sitting. Some people identified everyday actions that could prompt their exercise snacking, such as brushing teeth, boiling the kettle, or washing dishes. As they were part of the routine and usually occurred in the same spot, they could be linked with exercises suitable for that space, for example, balance exercises.

Topic 3—Opportunities and Challenges of Using Technology at Home

Finally, when discussing the use of technology, it was apparent that participants were already familiar with a range of technologies (eg, apps, Amazon Alexa, Fitbit for tracking steps, and YouTube videos to support exercise) and referred to existing solutions to highlight their strengths and weaknesses. On the basis of this previous experience, they had clear expectations of what technologies would work and would not work for them. For example, they all agreed that any system that aims to support PA at home should be discreet or even hidden, as not everyone felt comfortable “advertising” with technology that they were trying to be more active. In addition, such systems should also work for people with low technology literacy and be as simple and easy to use and set up as possible. As such, some participants also thought that limiting functionality would help to make the technology easy to use.

This need for simplicity was also linked with a need to consider the context of use. This included accounting for the realities of everyday life and characteristics of the users. A participant
mentioned that ideal technology would be something they could use without having to wear glasses. Another participant pointed out that the technology would be a part of a wide ecosystem and, therefore, would need to easily connect to the local wireless network and work with other devices at home. Furthermore, it should be inexpensive, as even smartphones or smartwatches were seen as being beyond the reach of a regular person.

Participants also identified several opportunities for exercise snacking technologies. They agreed that technology should provide instructions, feedback, and reminders. Instructions were seen as an important feature that could help to introduce the correct movements; help users understand how to exercise (e.g., frequency and when to stop); and later, help check whether they were exercising correctly, especially if no additional support was provided. Regarding the latter point, participants expressed a desire to have access to either support groups or someone they could discuss their progress with. Furthermore, visual prompts could also be used to provide ongoing feedback and situated instructions, for example, by showing the movements one is supposed to execute or simply providing encouragement to motivate the user. In addition, some participants thought that this type of interaction could be more playful and “witty.” Overall, participants were open to trying new technologies.

Prototype Development

Study-1 results informed the design of the prototypes. Given that participants expressed interest in exercise snacking and engaging with simple exercises at home, we decided to develop prototypes based around a pressure mat that could be placed anywhere at home, where it would fit best into participants’ daily routine. This form factor would also allow participants to just use it (stand or sit on it) without having to set things up in preparation, which was another aspect identified by participants. Finally, as participants expressed interest in systems that are discreet or hidden, a light-emitting diode (LED) companion screen was included to provide additional visual feedback that did not explicitly mention exercise.

We developed 2 prototypes. Each consisted of a pressure mat and a battery pack. We used SensingTex Switch mat that enabled a single pressure point recognition (Figure 2). We selected a pressure mat as the basis of each prototype, as it would not require any complex interactions, and participants would only need to stand on it if they were ready to exercise. Each mat was connected via Bluetooth to a Raspberry Pi 4 and a Unicorn HAT LED Matrix. The LED screen provided feedback to the user because without it, owing to the mat’s minimal interface, it was not clear whether the prototype was active or whether participants were reaching their goals. The screen also provided encouragement and motivation.

Although both prototypes appeared similar, they had different underlying algorithms to account for differences in the exercises. The balance mat was set up for 2 daily repetitions, 60 seconds each, as a default, and the sit-to-stand mat was set up to measure movement repetitions for 60 seconds during each exercise session, with the target of 30 repetitions per day. When stepped on, the prototype would trigger a timer, which was shown on the LED screen. The devices recorded the number of repetitions and time spent on each exercise. Figure 3 shows examples of the visual feedback—a smiling face if the daily target has been reached, a frowning face if it has not been reached yet, and a progress bar to help count down time during an exercise session.

A flow diagram showing how the prototypes worked is available in Multimedia Appendix 2.

**Figure 2.** A pressure mat and a battery pack that were used as a basis of the prototypes.
Study 2—Home Evaluation

The second study focused on evaluating the prototypes at home. Unlike study 1, it was more exploratory in nature—we did not have predefined topics in mind beyond understanding how the participants used the prototypes and what they thought about them.

Participants’ Use of Technology

All participants (5/5, 100%) reported using the internet and having previous experience in using mobile phones, laptops, PCs, and tablets. Consumer electronics they used were often Apple products, the sleek design of which was referenced by participants when discussing the study prototypes. Most participants (4/5, 80%) reported that they used some type of activity tracker (often step counters on their phone) and were generally positive toward these types of technologies. Of the 5 participants, 1 (20%) participant mentioned using a heart rate monitor and 2 (40%) reported watching exercise videos on YouTube (fitness and yoga) during the COVID-19 lockdowns to help them stay active.

These technologies and participants’ experiences influenced how they interacted with our prototypes and their expectations toward the devices. In the following sections, we describe 4 themes identified in the interviews conducted after the home evaluation.

Importance of Design Esthetics and Reliability

The study findings highlighted the importance of selecting the right level of complexity and polishing the design of initial prototypes used for testing. As the study’s goal was to explore how the technology fits into people’s homes and could support exercise snacking, we focused primarily on the functionality and did not prioritize the design at this stage. Therefore, our participants thought the prototypes were crude (“The graphics I thought were very crude. I think they could have been more pixels in the display to make the pictures easier to understand.” [Participant 5]) and unfinished (“That equipment was quite awkward, you know, the cables and the fittings and the plugs didn’t seem to fit very securely. It was all kind of it all looked a bit fragile.” [Participant 3]), which affected how they used them. Some participants were not sure whether they could fold the mats for storage or whether that would damage them.

Participants also found it cumbersome to assemble the prototypes and to remember to switch them on and off to preserve the battery. This led to technical issues when they connected things incorrectly or the prototypes were not working properly, which discouraged participants from using the devices. Therefore, although participants agreed that the devices had potential and “tools like this” could be useful, they did not see a clear benefit of using the prototypes in their current form:

The technology is too crude and intrusive at this early stage, compared with either a) doing without or b) doing something clever with it. [Participant 1]

Challenges With Fitting the Device Into Everyday Life

The prototypes were designed such that they could be used in different places at home to enable participants to fit exercise snacking into their routines. Although it mostly worked, participants highlighted a few practical considerations. A participant reported that they had to rearrange their house and move a chair to the kitchen so that they could do the sit-to-stand exercise:

I’ve got lots of things all over the place. For this trial, I put them in the kitchen. But it would be in the way if I left there every day. I’d have to find somewhere else. [Participant 1]

In addition, the balance mat was perceived as a potential trip hazard and participants were not keen to leave it on the floor when not in use:

If I kept it there during the day, I could easily trip on it. Anybody could trip or slip as well because I have a wooden floor so it could slip quite easily. [Participant 2]

In addition, some did not want the prototypes to always be visible owing to their looks and found packing and unpacking the devices to be cumbersome. Similarly, the limited battery life required the device to be switched off when not in use, which added an extra burden.

Overall, although exercise snacking was supposed to be easy and effortless, having to set things up defeated the purpose of the prototypes. Participants acknowledged that although having a dedicated tool could, in principle, make exercising easy, using preexisting methods or devices was perceived as easy and more...
useful. Improved reliability, more polished look, and easy set up would make exercise snacking systems more motivating and appealing:

I think [the prototypes] just feel, um, they don’t feel user friendly and they don’t feel...they feel like old technology. I think it would need to have a screen; it would need to look like a phone; it would need to have a digital reader, you know, all of that, like the apps we have on our phone. [Participant 3]

**Need for Personalization**

The initial design of the prototypes allowed changes to the difficulty levels and the number of repetitions. However, in scaling down the project owing to the COVID-19 pandemic, the researcher gave all participants (5/5, 100%) the same device with default settings. This proved to be problematic, and participants consistently commented that the exercises were either very easy or very difficult:

The balance exercise is quite easy, and the sit-to-stand is more strenuous. It’s hard work. It takes more energy and makes me tired. [Participant 5]

A positive side effect observed was increased motivation of a participant who started using weights to make the exercises more challenging (“I put a rucksack on my back and weights in it and I did it like that to get myself...to make [sit-to-stand exercises] harder.” [Participant 3]), which suggested that the device could be useful for initiating exercise behavior or as a gateway to people forming a new routine:

If it’s there, you’ll use it. And that’s just getting into the regime, it’s like, in the morning, you’ll sort of do 10 minutes of different exercises...And it just becomes a habit. [Participant 4]

Issues with difficulty levels and progression led to discussions about exercise personalization and suggestions for future improvements. Participants believed that exercises needed to be adapted to the user and therefore suggested including some progression to keep users engaged, for example, by increasing the complexity or difficulty of movements:

Trick is to make it sufficiently interesting and challenging to those who find it fairly easy, but also not to put off people who find it harder and struggle to get out of the chair; so maybe if you had a series of levels so you could come in at level one or you could jump to level three. [Participant 3]

They also highlighted the need for feedback about the movements and progress, which would help with motivation and could support the increasing difficulty levels (a participant suggested a potential app similar to the Couch to 5K running program but for strength and balance).

**Future Opportunities**

When asked for views about the potential of technology to support home-based exercise after using the prototypes, participants identified several desirable features to improve utility. Features included linking of the devices to a more sophisticated app or sensors to provide more detailed feedback (“If the mat sensed the growing extent of my imbalance and reduced the time, or increased it if my balance was perfect, that would be a bit more useful, and if it sensed where my toes or heel or whatever was going wrong, and issued warnings about posture then that would make it more useful.” [Participant 1]), adding voice or sound as a way of providing feedback about performance of exercises and encouragement, and prompts and reminders to do the exercise.

Participants also discussed how the prototypes could be improved. Some suggestions focused more on how the mat could support a more diverse array of exercises:

It would be nice to have a wider range of exercises. I mean, as you get old your backs get stiff. You get stiffness in lots of joints. I think that it could be done to use more joints as a body, try and create more flexibility. [Participant 5]

Participants also provided positive perspectives about the role of technology in supporting home-based exercise, for example, providing visual prompts:

The little pad would be sitting on the floor, would be a reminder. [Participant 5]

Others discussed how functioning technology could provide structure to support current activity and could be useful for engaging people in new activities in the short term, even if not used continuously:

At the moment I do it when I can see I’ve got two or three minutes to do sit to stand. So I do. [Participant 1]

**Discussion**

**Principal Findings**

**Overview**

The aim of this project was to develop and test interactive prototypes to be used at home to support strength and balance exercise snacking in older adults who are prefrail. Our workshops identified that participants were open to using technology in the home setting, but personalization of the exercise snacking regime and simplicity in technology use are important. Participants who subsequently tested 2 prototypes (balance mat and sit-to-stand mat) in a home evaluation demonstrated that this technology had the potential to support exercise snacking in the home setting with further development and testing. In the following sections, we discuss the main results and implications for designing systems that support exercise snacking at home for older adults who are prefrail.

**Home Environment as a Space to Exercise**

Exercise was identified as an important activity for participants, and using the home setting as a location for exercise snacking elicited both positive and constructive views, which will inform the next iterative step in the design process. The home setting has been frequently used for rehabilitative exercise for multiple conditions such as musculoskeletal joint replacement, neurological conditions, and cardiorespiratory conditions and has been shown to be as effective as supervised or group exercise at 12 weeks on health outcomes for women with type
Role of Technology for Overcoming Barriers

A key challenge for any exercise program, especially those targeting individuals in the home setting, is prolonged adherence [36]. Participants in this study were largely positive about the potential for technology to support the implementation of home-based exercise snacking as long as the technology was simple, reliable, and unobtrusive to use. The need for simplicity and reliability as key guiding principles for the adoption and sustained use of technology has been found in other studies of older adults’ perceptions about technology [37]. Technology, if designed appropriately, also enables the integration of some key behavioral science principles that can help with exercise motivation, such as self-regulatory behavior change techniques (eg, feedback and goal setting) and gamification to make exercise fun and engaging [37-39], and nudges or cues to help turn exercise into a more automatic behavior [40]. Our preliminary evaluation suggested that more work could be done to improve the reliability of the technology, better integrate feedback, and make the device more personalized to the user’s needs and preferences for exercise.

Recommendations for Future Practice and Studies

Accordingly, we provide design recommendations for developing home-based systems that support exercise snacking and other types of PA aimed at older adults. Researchers and developers working in this area should do the following:

1. **Support personalization**—As older adults can have varying levels of activity, any home-based system that facilitates and supports exercise needs to be able to accommodate different baseline circumstances, from fully sedentary routines to physically active users who may want to move more at home. As such, systems should allow users to change difficulty levels, which should then progressively adapt based on the user’s progress.

2. **Provide clear and meaningful feedback**—As exercise snacking is a situated activity, any system that supports it needs to recognize and clearly communicate that it has started and notify the user when they can finish, regardless of whether they are doing timed exercises or a specific number of repetitions. It should also notify the users when they reach their goals and show their progress. Furthermore, different feedback modalities need to be considered to improve accessibility and usability through combinations of visual and auditory feedback to support older adults with hearing and visual impairments.

3. **Take the environment into account**—Any system that supports exercise at home needs to be sufficiently flexible, so that people can use it in the most suitable location. Different people have different routines, and the living situation of older adults varies, which makes it impractical to design a one-size-fits-all solution. For example, some people may prefer to exercise snack in the living room, whereas others would prefer to do so in the kitchen; ideally, the system should work in both.

4. **Remember the esthetics**—The design of technologies aimed at older adults is often based on a wrong assumption that esthetics do not matter for this user group. However, increasing access to consumer electronics influences the perceptions about technology and people’s expectations and values; older adults are not different [41]. Furthermore, any device that is meant to become part of an environment should fit into that environment and ideally provide subtle and discreet feedback, as not all users may want to advertise to visitors that they are trying to be more active.

5. **Ensure the system is accessible and easy to use**—As older adults’ experiences with technology or digital literacy may be limited, any system aimed at them should have an intuitive design and require minimal setup. Switching technology on and off and selecting user goals and preferences should be implemented in a user-friendly manner that is suitable for the target population. Furthermore, systems should be compatible with the technologies that people already have at home, for example, wireless networks. As most IoT systems rely on the internet connection, the ease of setup and seamless connectivity are key.

6. **Provide guidance to reduce risks**—Finally, any system that supports PA needs to be able to guide the users, as the movements may not be familiar to them or they may require a reminder. This can be directly embedded in the physical system or be provided through a companion app. Regardless of the format, guidance could help to reduce risks of falls, support older users, and educate users about PA.

Limitations and Future Studies

This was an exploratory project focusing on the early stages of the iterative UCD process and as such had some limitations. Study-1 participant numbers were limited by space and maximum capacity for people in the smart home at the time; however, the numbers were consistent with those in previous design research using workshops to design digital interventions [42]. Study 2 involved 5 participants who used the prototypes for 1 day. As our goal was to assess the usability of the prototypes and gather early feedback, this was sufficient, because usually 4 to 6 participants are required to identify key usability issues [43]. Participants were vocal about issues and constructive suggestions for improvement. Overall, our participant numbers are consistent with UCD studies, and evidence has shown that these methods can provide generalizable design guidelines [44-47].

Participants were recruited from a cohort that had previously participated in a PA trial [48], albeit a mixture of intervention and control participants. Selection bias may have influenced the results obtained, as the participants may have had more positive attitudes toward PA. However, as this was the initial phase in the design process, both benefits of and challenges to developing technology were identified, and future stages in this process (acceptability, feasibility, and efficacy testing) will ensure a wide, representative, and large recruitment of older adults who are prefrail to avoid potential bias [49]. In addition,
recruitment from this population enabled participants to reflect about their previous experiences with exercise snacking and provide feedback and suggestions for improvement, which was crucial for this study.

Study 2 was a home study conducted during the COVID-19 pandemic and, consequently, was subject to several deviations from the initial protocol. These limitations influenced the participants’ experiences, which is reflected in the themes. Nevertheless, key lessons were learned about the design and delivery of technology home testing during COVID-19, which can be embedded in the future stages of this project to ensure successful delivery and completion, regardless of whether there is face-to-face or remote delivery. Furthermore, as home testing occurred over a single day, we were unable to evaluate the adherence to exercise snacking. As adherence is crucial to the acceptability and feasibility of the exercise snacking technology design, factors predicting adherence to home-based rehabilitation (intention to engage, self-motivation, self-efficacy, previous adherence, and social support [50]) will be incorporated into subsequent iterations of the design process.

Finally, the design of our prototypes may have influenced the results. Our primary focus was the functionality of the prototypes; we did not fully consider aesthetics or visual design at this stage. This resulted in negative comments and, to some degree, affected participants’ interactions with the prototypes. Although we were still able to gather relevant feedback, more polished prototypes and user interfaces would have helped to concentrate the feedback on functionality. As we are following the UCD process, this will be incorporated into the next iterative phase of development of the prototypes.

Conclusions
Exercise snacking offers a promising approach for incorporating balance and strength PA into older adults’ routines. Our results demonstrated that technology has the potential to support exercise snacking in the home environment for older adults who are prefrail. However, the design of devices not only needs to be easy to use and set up but must also fit into users’ routines and physical spaces. Exercise snacking technology devices also need to be adaptable and personalized to individuals, to ensure that users are snacking on balance and strengthening exercises that are appropriate for them.

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Data Availability
The data sets generated and analyzed during this study are available from the corresponding author upon reasonable request.

Conflicts of Interest
None declared.

Multimedia Appendix 1
A table with quotes to illustrate the subthemes identified in the workshops for each discussion topic.

[PDF File (Adobe PDF File), 203 KB - aging_v6i1e41810_app1.pdf]

Multimedia Appendix 2
A flow diagram showing how the prototypes work.

[ PNG File, 127 KB - aging_v6i1e41810_app2.png]

References


Abbreviations

- IoT: Internet of Things
- LED: light-emitting diode
- NFC: near-field communication
- PA: physical activity
- SPHERE: Sensor Platform for Healthcare in a Residential Environment
- UCD: user-centered design

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Video Calls as a Replacement for Family Visits During Lockdowns in Aged Care: Interview Study With Family Members

Abstract

Background: Lockdowns have been used to prevent the spread of transmissible illnesses such as influenza, norovirus, and COVID-19 in care homes. However, lockdowns deny care home residents supplemental care and the socioemotional enrichment that comes from seeing family members. Video calling has the potential to enable ongoing contact between residents and family members during lockdowns. However, video calls can be considered by some as a poor substitute for in-person visits. It is important to understand family members’ experiences with video calling during lockdowns to ensure the effective use of this technology in the future.

Objective: This study aimed to understand how family members use video calls to communicate with relatives living in aged care during lockdowns. We focused on experiences during the COVID-19 pandemic, which involved extensive lockdowns in aged care homes.

Methods: We conducted semistructured interviews with 18 adults who had been using video calls with relatives living in aged care during pandemic lockdowns. The interviews focused on how participants had been using video calls, what benefits they gained from video-based interactions, and what challenges they encountered when using the technology. We analyzed the data using the 6-phase reflexive approach to thematic analysis by Braun and Clarke.

Results: We developed 4 themes through our analysis. Theme 1 interprets video calling as a medium for the continuation of care during lockdowns. Using video calls, family members were able to provide social enrichment for residents and engaged in health monitoring to uphold residents’ welfare. Theme 2 highlights how video calling extended care by supporting frequent contact, transmitting nonverbal cues that were essential for communication, and negating the need for face masks. Theme 3 interprets organizational issues such as the lack of technology and staff time as impediments to the continuation of familial care through video. Finally, theme 4 highlights the need for 2-way communication, interpreting residents’ unfamiliarity with video calling and their health conditions as further barriers to the continuation of care.

Conclusions: This study suggests that, during restrictions arising from the COVID-19 pandemic, video calls became a medium for enabling family members to continue participating in the care of their relatives. The use of video calls to continue care illustrates their value for families during times of mandatory lockdown and supports the use of video to complement face-to-face visits at other times. However, better support is needed for video calling in aged care homes. This study also revealed a need for video calling systems that are designed for the aged care context.

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KEYWORDS

aged care; COVID-19 pandemic; lockdowns; older adults; video calls; videoconferencing; mobile phone; COVID-19
**Introduction**

**Background**

Lockdowns are a common measure for preventing the spread of viral diseases in aged care homes [1,2]. In recent years, lockdowns have been used to slow the spread of COVID-19 in care homes worldwide [3,4]. These lockdowns were essential because of considerable outbreaks of COVID-19 within care facilities [5,6] and because care home residents were highly susceptible to mortality from the disease [7]. Examples of measures implemented during lockdowns include the confinement of residents to their rooms and the suspension of all face-to-face visits from family and friends [8-10].

Although lockdowns can be an effective way to prevent disease transmission, prolonged periods of isolation are highly detrimental to the cognitive and emotional well-being of care home residents [11]. Loneliness and isolation have long been salient problems in aged care [12,13], and there is evidence suggesting that these problems worsened during the pandemic lockdowns [10,14]. This can be partly attributed to the loss of physical visits from residents’ family members, who were not able to visit in person while restrictions were in place [15]. Beyond the positive health and well-being effects of visits from family [16,17], family members have been described as “central to the care of residents” [14]. Families are a primary source of cognitive and emotional enrichment [18] and contribute to advocacy, emotional support, and assistance with the personal care of residents [14,19-21]. The loss of such support during the pandemic restrictions has placed renewed focus on enabling meaningful communication between residents and families during lockdowns [9,22,23].

After the onset of the pandemic, many aged care homes adopted video calling systems as a replacement for face-to-face visits [13,24]. These systems—which include Skype (Skype Technologies), FaceTime (Apple), and Zoom (Zoom Video Communications)—allow 2 or more people to see each other and participate in real-time conversations using high-fidelity video and audio feeds transmitted over the internet [25]. Several studies have used survey methods to understand the availability of video calling hardware during the pandemic [26,27] and whether care homes had to adjust the provision of technology for social connection [13]. These studies provide important data to illustrate care providers’ adoption of video calling but do not offer insights into the experiences of people who had to rely on video calling in lieu of face-to-face visits during the lockdowns.

The need to understand the utility of video calling as a replacement for face-to-face visits, especially during lockdowns, is important for multiple reasons. First, the pandemic was perhaps the first time that video calling was deployed en masse in care homes. There have been studies illustrating the benefits of video calls for aged care residents, including positive impacts on social connection [28], emotional enrichment [29], and feelings of depression and loneliness among residents [30]. However, many such studies have involved short-term trials coordinated by research teams in which residents used video calls with relatives who could not visit the care home [28,31,32]. This setup partially replicates the circumstances of a lockdown, but it may not capture issues and experiences that arise in real-world use when support from researchers is unavailable.

The recent lockdowns because of COVID-19 afford an important learning opportunity in this regard given that care homes had to pivot quickly to using the technology without external support from research teams.

Second, studies conducted before and during the pandemic have identified that video calling is affected by challenges in long-term care. A study conducted in Canada by Chu et al [33] found that essential family caregivers were highly dissatisfied with the provision of video calls during the lockdowns. The reasons given included poor internet availability, unsuitable devices, and technical problems, all of which have been identified as barriers in previous work [27,31,34]. Moreover, many aged care residents are frail, have complex health conditions such as dementia, and have little experience with information and communications technologies. These issues may make it hard for them to use commercial video calling systems [35,36], and care staff usually need to provide extensive assistance [37]. However, care staff typically have limited time for activities that fall outside their core duties [27,32], meaning that video calling risks placing additional burdens on an already overstretched workforce [37]. In addition, staff shortages were prevalent during the COVID-19 pandemic owing to high rates of infection within care homes [38]. These issues may have affected the quality of experience for residents and their families, but there remains scant understanding of people’s experiences of video calling as a substitute for in-person visits during the restrictions.

**Objectives**

This study aimed to understand how family members used video calls to communicate with relatives living in aged care homes during COVID-19 lockdowns. We focused on experiences of video calling in Australia, where there were extensive and protracted lockdowns that prevented families from visiting relatives during the first 2 years of the pandemic.

This study explored the following questions:

1. How did family members use video calling with relatives in aged care during lockdowns?
2. In what ways was video calling beneficial for family members?
3. What challenges or barriers need to be overcome to support high-quality video calling experiences during lockdowns in aged care?

**Methods**

**Ethics Approval**

This study was approved by the University of Melbourne Human Research Ethics Committee (ID 1851239.5).

**Study Design**

This study used semistructured interviews to investigate family members’ experiences with video calling. We used a semistructured approach to guide each interview using a broad set of questions while enabling participants to bring their own topics and experiences into the conversations [39].

https://aging.jmir.org/2023/1/e40953
The reflexive thematic analysis (RTA) approach by Braun and Clarke [40,41] was used to analyze and interpret the data. RTA champions the researcher’s interpretation as central to making sense of and generating meaning from qualitative data [41]. This means that RTA does not attempt to define a codebook or demonstrate validity based on metrics such as interrater reliability [42,43]. Rather, the emphasis is on the researcher’s reflexive engagement with data and on interpretation developed through iterative rounds of coding and analysis. The goal of RTA is to develop themes that capture patterns of shared meaning relevant to the research questions [44,45].

Consistent with the assumptions of RTA, we adopted a constructionist and experiential orientation for our data collection and analysis. This means that we prioritized participants’ own accounts of their experiences while using our interpretations to interrogate the meaning within those experiences [43]. We adopted RTA as we did not enter the study with a specific theory or deductive lens through which to interpret the data. RTA provided the flexibility to incorporate relevant theory and use existing knowledge on video calling to inform and develop the evolving analysis [41].

Research Context

We collected data for this study from July 2021 to October 2021 in the state of Victoria, Australia. Victoria was the site of several major COVID-19 outbreaks in 2020 and 2021. The state government imposed a total of 6 lockdowns that lasted a cumulative 8 months [46]. These lockdowns involved measures such as mandatory social distancing, stay-at-home orders, and the use of face masks both indoors and outdoors [47]. Aged care facilities in Victoria had to adhere to these restrictions, with many imposing bans on visitors because of COVID-19 outbreaks among residents and staff [48]. These restrictions meant that the participants in this study were reliant on video calls as their primary method of seeing relatives during the lockdowns.

Participant Recruitment

We recruited participants through the University of Melbourne internal staff mailing list and web-based noticeboards, advertisements on Twitter and LinkedIn, and word of mouth. Participants enrolled in the study by contacting the first author via email. There were no preexisting relationships before study commencement.

Our sample size was evaluated throughout the research process [49], and we stopped recruiting after 18 participants had completed the study. In line with RTA, we do not claim this as evidence of data saturation [50]. Rather, we ceased recruitment as the lead researcher (RMK) made the assessment that the data contained sufficient information power to address our aims and research questions [41,49]. Specifically, we felt that no further participants were required as our study had a narrow aim (to understand video calling in aged care); our sample specificity was dense (family members); and participants had conveyed rich experiences, indicating a strong quality of dialogue [49].

Procedure

Interviews were one-to-one and were conducted by the first author. Before study commencement, we emailed participants a Plain Language Statement containing information about the study’s aims and procedures. Participants also signed a consent form, which they returned to the first author via email.

The researcher met with participants individually using Zoom videoconferencing software. We used Zoom to comply with social distancing requirements, which were in place when our data were collected. We used a semistructured interview guide, with an initial set of open-ended questions that enabled participants to share their personal experiences (see Multimedia Appendix 1 for the questions). The interview questions were developed as a team, drawing on our collective experience of research on digital communication technologies [51,52], older adults [53,54], and aged care [29,55]. The researcher took notes during the interviews and asked follow-up questions to probe responses in detail. The interviews lasted 19 to 47 (mean 32, SD 9) minutes. All interviews were audio recorded with participants’ consent. Each participant received an Aus $30 (US $20.02) digital gift voucher for their time.

Analysis Approach

Recordings of the interviews were transcribed and combined with the researcher’s notes from each interview. A pseudonym was assigned to each participant to ensure anonymity. We analyzed the data using the 6-phase approach to RTA by Braun and Clarke [40]. The lead researcher (RMK) conducted the analysis as follows.

Phase 1 involved familiarization with the data. RMK read through each transcript twice using Microsoft Word (Microsoft Corp). RMK highlighted passages that were relevant to the research questions and used the comment functionality to capture potential codes and thoughts about the data [43]. In phase 2, RMK imported the data into NVivo (QSR International) and coded each interview using an inductive, data-driven approach. RMK coded the interviews at the sentence level and created codes to capture key ideas. Some codes were semantic (ie, those that captured overt ideas), whereas others were latent codes (ie, those reflecting the researcher’s interpretations) [41]. An example semantic code was peace of mind, which was a phrase used by participants, whereas a latent code was using video calls to monitor health. Consistent with other examples of RTA [43], we made no attempt to prioritize either form of code. RMK revised and refined the names of the codes as he progressed through the data and used annotations within NVivo to capture additional reflections.Textbox 1 provides an example of a coded data extract [56].

In phase 3, RMK assembled the codes into initial candidate themes by manually grouping codes using NVivo and sketching thematic maps using pencil and paper. RMK discussed the evolving analysis with author YX, who also read through the coded data, sense-checked interpretations, and reviewed the candidate themes.

In phase 4, RMK refined the themes and discussed them with author JW. The authors felt that an initial “benefits and challenges” framing could be helpful to capture the essence of

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Textbox 1

Challenges framing could be helpful to capture the essence of

---
participants’ experiences. This discussion resulted in 6 initial subthemes related to benefits and 5 subthemes related to challenges. In phase 5, RMK defined and named each theme, selecting participant quotes and data extracts to illustrate key ideas. Phase 6 involved writing an initial draft of the report, which involved further theme refinement [41].

After receiving feedback and peer reviewers’ comments on the report, RMK went back through phases 3 to 6 and revised the themes to develop primary interpretations and address the research questions. We also changed our framing to focus on the continuation of care, removing the initial ideas regarding benefits and challenges. Returning to earlier phases in this way is consistent with the tenets of RTA, which champions iteration and argues that analysis “becomes increasingly recursive” [45] as the interpretation progresses. RMK and JW also reviewed the themes to consider whether each one was sufficiently anchored to a central organizing concept [42]. Finally, RMK created a table to describe how the analysis activities align with guidance on establishing trustworthiness in the 6 phases of thematic analysis (Multimedia Appendix 2 [57]). This was done to provide evidence of a trustworthy and credible analysis [58]. From this iterative process, our analysis converged on the central interpretation of video calling as enabling the continuation of care during lockdowns. That is, video calls were not simply a medium for social connection but were being used to continue care practices that would ordinarily take place during face-to-face visits. We created one theme to capture uses that spoke to continuation of care and a second theme to highlight how video calling extended care. We developed 2 further themes: one that interprets organizational issues as impediments to continuing care through video calling and another that highlights the need for 2-way communication for continuation of care. The Results section details these themes after presenting demographic data on the participants.

Textbox 1. Example data extract from the interview with participant 7 (Gloria) and codes associated with the extract.

<table>
<thead>
<tr>
<th>Data extract</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMK: How do you think going on the video calls helps with that?</td>
</tr>
<tr>
<td>Gloria: I don’t really know that it does help him, but it certainly helps me because I’m reassured seeing that he’s all right or not too bad. And I have noticed particularly, if I don’t see him, if the video call doesn’t come about, then I go in [to see him] and I go, “Oh, he’s gone downhill.” So, it’s more noticeable that way. It’s very, very lonely for him being in there, he’s really not communicating with other residents because of the PSP. So, he’s just either stuck in his room or sitting, looking out of the window in the lounge areas.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling reassured by video calls</td>
</tr>
<tr>
<td>Importance of visual information and seeing the resident</td>
</tr>
<tr>
<td>Concern about resident decline</td>
</tr>
<tr>
<td>Resident loneliness</td>
</tr>
<tr>
<td>Communication impairment</td>
</tr>
<tr>
<td>Family members are concerned for residents’ emotional well-being</td>
</tr>
</tbody>
</table>

Results

Participant Characteristics

We recruited a total of 18 participants (n=15, 83% women and n=3, 17% men) between the ages of 20 and 76 (mean 48, SD 17.3) years. Table 1 lists the participants using pseudonyms along with the relatives they discussed and the technologies they used for the video calls.

Of the 18 participants, 17 (94%) participants lived in Australia, in the state of Victoria, and 1 (6%) participant (Margaret in Table 1) lived in New Zealand but was an expatriate who used video calling to contact her parents in an Australian care home. All had experience living under lockdown conditions in their respective places of residence.

Participants discussed using video calls with a total of 22 relatives, all of whom lived in residential aged care. Of the 22 relatives, 17 (77%) were living in Australia, and 5 (23%) were living in care homes abroad (n=2, 40% in the United States; n=2, 40% in Japan; and n=1, 20% in Italy). The relatives’ ages ranged from 69 to 98 (mean 84, SD 7.3) years. Of the 22 relatives, 18 (82%) were described as having at least one health condition or impairment that affected their use of video calls (Table 1). All the relatives had endured periods of lockdown or isolation at the care homes in which they lived.

All participants had been using video calling with their relatives living in aged care during the pandemic. However, video calling was a new activity for 44% (8/18) of the participants. These individuals had previously visited their relatives in person but turned to video calls during the lockdowns. The remaining 56% (10/18) of the participants had some previous experience using video calling with their relatives in care before the emergence of COVID-19 but became solely reliant on the technology during lockdown periods.
Table 1. Participant characteristics and details of the relatives they discussed. All names are pseudonyms.

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Gender</th>
<th>Relative or relatives discussed</th>
<th>Relative’s age (years)</th>
<th>Relative’s impairments affecting use of video calls</th>
<th>Video calling software used</th>
<th>Video calling hardware used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alison</td>
<td>Woman</td>
<td>Mother</td>
<td>80</td>
<td>Advanced dementia</td>
<td>Zoom</td>
<td>iPad</td>
</tr>
<tr>
<td>Ben</td>
<td>Man</td>
<td>Father</td>
<td>83</td>
<td>N/A</td>
<td>Facebook Messenger</td>
<td>Kindle Fire</td>
</tr>
<tr>
<td>Charmaine</td>
<td>Woman</td>
<td>Father</td>
<td>75</td>
<td>PSP\textsuperscript{d}, nonverbal, and slightly deaf</td>
<td>FaceTime and Zoom</td>
<td>Laptop and smartphone</td>
</tr>
<tr>
<td>Deborah</td>
<td>Woman</td>
<td>Mother</td>
<td>86</td>
<td>Advanced dementia</td>
<td>Zoom</td>
<td>iPad</td>
</tr>
<tr>
<td>Elaine</td>
<td>Woman</td>
<td>Father</td>
<td>69</td>
<td>Left-side paralysis because of stroke</td>
<td>Facebook Messenger</td>
<td>Laptop</td>
</tr>
<tr>
<td>Fiona</td>
<td>Woman</td>
<td>Mother</td>
<td>78</td>
<td>Moderate dementia</td>
<td>Facebook Messenger</td>
<td>Smartphone</td>
</tr>
<tr>
<td>Gloria</td>
<td>Woman</td>
<td>Husband</td>
<td>82</td>
<td>PSP</td>
<td>Zoom</td>
<td>iPad</td>
</tr>
<tr>
<td>Hannah</td>
<td>Woman</td>
<td>Grandmother and grandfather (married)</td>
<td>75 and 84</td>
<td>Vision impairment and noticeable cognitive decline (grandmother)</td>
<td>WhatsApp</td>
<td>Smartphone</td>
</tr>
<tr>
<td>Irene</td>
<td>Woman</td>
<td>Mother</td>
<td>90</td>
<td>Dementia</td>
<td>Zoom</td>
<td>iPad</td>
</tr>
<tr>
<td>Jackie</td>
<td>Woman</td>
<td>Mother</td>
<td>88</td>
<td>Advanced dementia, nonverbal, and cannot use her hands</td>
<td>Zoom</td>
<td>iPad</td>
</tr>
<tr>
<td>Katherine</td>
<td>Woman</td>
<td>Mother</td>
<td>98</td>
<td>Deafness and vision impairment</td>
<td>Zoom</td>
<td>Laptop and smartphone</td>
</tr>
<tr>
<td>Luca</td>
<td>Man</td>
<td>Father</td>
<td>90</td>
<td>Moderate dementia and frail with limited mobility</td>
<td>FaceTime</td>
<td>iPad and smartphone</td>
</tr>
<tr>
<td>Margaret</td>
<td>Woman</td>
<td>Mother and father</td>
<td>86 and 87</td>
<td>Dementia (mother) and cognitive impairment and memory problems (father)</td>
<td>Zoom</td>
<td>Laptop</td>
</tr>
<tr>
<td>Nicole</td>
<td>Woman</td>
<td>Mother</td>
<td>92</td>
<td>Dementia, nonverbal, and limited mobility</td>
<td>Zoom and Face-Time</td>
<td>Laptop and smartphone</td>
</tr>
<tr>
<td>Olive</td>
<td>Woman</td>
<td>2 great-aunts</td>
<td>91 and 94</td>
<td>N/A</td>
<td>FaceTime and Facebook Messenger</td>
<td>Smartphone</td>
</tr>
<tr>
<td>Paul</td>
<td>Man</td>
<td>Grandmother</td>
<td>84</td>
<td>Deafness and rheumatoid arthritis</td>
<td>Zoom</td>
<td>iPad and smartphone</td>
</tr>
<tr>
<td>Quinn</td>
<td>Woman</td>
<td>Grandmother and grandfather (married)</td>
<td>74 and 77</td>
<td>Deafness (grandmother)</td>
<td>Skype</td>
<td>Laptop</td>
</tr>
<tr>
<td>Robin</td>
<td>Woman</td>
<td>Grandmother</td>
<td>87</td>
<td>Advanced dementia</td>
<td>FaceTime</td>
<td>iPad and smartphone</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Denotes that video calling was a new activity adopted only after the onset of the COVID-19 pandemic.
\textsuperscript{b}Denotes that the participant’s relative or relatives lived in an aged care facility outside Australia.
\textsuperscript{c}N/A: not applicable.
\textsuperscript{d}PSP: progressive supranuclear palsy.

**Theme 1: Video Calls as Enabling the Continuation of Care**

**Summary**

This theme responds to our initial question of how video calling was used by family members. The central idea developed through our analysis was that video calling enabled family members to continue participating in the care of their relatives during lockdowns. In other words, video calls provided a way to maintain some of the activities that typically occur during a face-to-face visit. Specifically, participants discussed using video calls for social enrichment and for monitoring residents’ health—both of which would ordinarily take place in person. These uses can be interpreted as relevant to the provision of care—one is about providing social and emotional care, whereas the other is about monitoring physical and mental well-being. Both are about ensuring that the resident is being “cared for” in an appropriate way.
“It’s So Good to See Them”: Using Video Calls to Continue Social Enrichment

The first aspect of continuing care was demonstrated through participants’ descriptions of providing social enrichment when physical visits were not possible. These accounts were often couched in the need to prevent “decline.” Gloria, for example, discussed the welfare of her husband, who had moved into care because of progressive supranuclear palsy. She said that her husband had become “very lonely” during the lockdowns. Therefore, video calling was her husband’s primary source of social enrichment, and Gloria felt that there was a clear and noticeable impact on his well-being if video calls did not occur. Upon visiting him in person between lockdowns, she observed the following:

I have noticed particularly, if I don’t see him, if the video call doesn’t come about, then I go in [to see him] and I go, “Oh, he’s gone downhill.” So, it’s more noticeable that way. It’s very, very lonely for him being in there, he’s really not communicating with other residents because of the PSP. So, he’s just either stuck in his room or sitting, looking out of the window in the lounge areas.

Participants described diverse uses of video calls for the continuation of social enrichment. In some cases, video calls were used for short “catch ups” and “chit-chat,” which provided opportunities to share updates about happenings outside the care home, keeping the resident involved in family life. Other cases involved the use of video calls for in-depth relationship maintenance. Quinn described how Skype calls with her grandparents would typically last over an hour and would involve different activities:

I always use my laptop when we Skype and I share my screen when I want to show them something. It’s always good to show them photos of everything while we are Skyping so that we can talk about them together. And we also watch videos together sometimes.

Quinn’s quote shows how video calls were used to mediate intergenerational activities that constitute an enriching social life and that would otherwise be impossible during lockdowns without using technology. Video calls were also used to continue with other events and social situations. Katherine described how, when it was her mother’s birthday, she was able to visit the facility between lockdowns and use a video call to host a celebration with extended family members:

When it was her 98th birthday in June (2021), I took my laptop in...Then my brother and I had the laptop and we Zoomed my other brother. We had him sort of in the background, chatting away while we had a birthday cake and some of the staff came in with more cake.

Although these findings reinforce the notion that video calls can support social connections between family members and care home residents [28,31,59-61], we interpret them as the continuation of care. That is, family members wanted residents to feel cared for and know that someone cares about them. This was reinforced by descriptions of the positive emotional outcomes that arose from video calls and how they benefited residents:

I have a four-year-old son, so I try to get him to say hello too, which always puts a smile on dad’s face...then if I’m at home with my son, I can put him on and my husband and we can all say hello. [Charmaine]

[Dad] would be happy and smile and be positive about having received our calls. It’s good for him to see us and remember us, and to see my mother and talk to my mother and me and my brother. [Luca]

“It’s Important to Have My Own Sense of His Health”: Using Video Calls to Continue Health Monitoring

The second aspect of continuing care involved family members using video to monitor the health of their relatives. Outside of a lockdown, such monitoring might naturally occur as part of a physical visit. The fact that this took place through video calls further evidences their use for continuation of care.

For participants such as Jackie, monitoring her mother’s health was a key motivator for adopting video calls during lockdown. She felt that information from care staff was useful but not entirely sufficient, and she expressed a need to do “checking up” on her mother:

When we went into lockdown, we couldn’t see how she was. She can’t talk to us. Even though the nursing staff will give us some information, you still want a little bit of checking up, if you know what I mean? So we started to have Zoom meetings with her.

Participants described making inferences about their relatives’ health during video calls based on visual appearance and the tidiness of their living environment. These actions can be understood as constitutive of care given that they represent attempts to determine whether something is wrong and, hence, whether intervention is required. Olive described how she used video calls to check for what she called “signs of deterioration”:

I’m attuned to looking for particular things. Have they done their hair? Have they done their nails? What’s their environment like? Are they taking care of themselves? Are their clothes clean? Those kinds of things are very important to me. That’s part of me knowing that they’re in good health, because that’s how they normally present themselves.

A participant, Ben, provided a compelling example in which he used a video call to infer that his father had contracted COVID-19. His father had previously tested negative for the disease following an outbreak within his facility, but interactions during a video call convinced Ben that further action was required. The following extract reveals how Ben’s intervention led to his father receiving treatment and emphasizes the role of the video call in making his assessment:

I noticed things were off in his voice. And I just kept asking him, “Are you okay?” And it finally led to me saying [to the staff], “I think you need to test him again.” I just got the sense that he wasn’t well. Based
on how he looked, how he was physically presenting on the video, as well as how he sounded. And don’t take the audio too far on that one, because I think a lot of it came from his visual appearance. He just doesn’t look well. They wound up finally having a closer look and he was eventually taken to the hospital and treated [for COVID-19].

In addition to monitoring health and well-being, Ben’s quote alludes to the role of video in enabling participants to advocate for care to be provided. In this case, Ben contacted the staff via telephone and requested additional care. Another participant, Fiona, described how video calls enabled discussions with other family members when monitoring the health of her mother, who was living with dementia:

_Having the video is good, especially for her sake. I can see her health and how she’s behaving. Because my brother will say, “Her memory’s not good. She’s kind of spacey,” and it’s one thing to say it, but then for me to actually see her and how she behaves, it’s a lot easier._

Here, Fiona used video to verify information obtained from other people—in this case, her brother—when maintaining an understanding of her mother’s health. Video calls also provided the opportunity to speak with nursing staff at the care homes. Gloria described how she would often be able to speak to staff during the video calls. This helped relieve anxiety about her husband’s well-being:

_I can ask them questions about how he’s been, “Is he depressed today? Because he has been quite depressed.” And they can reassure me or say, “Look, talk to him for a few minutes.”_

Using video calls in this manner helped participants alleviate feelings of anxiety and provided “peace of mind.” For example, Olive told us that using video enabled her to feel reassured about her aunt’s welfare when she could not visit:

_I was able to physically see in the room, and I was able to make sure that she had the things that she needed. Now, she was fine, but the peace of mind it gave me that the room was clean, that her personal effects weren’t being interfered with, that she had the basics...Those sorts of things are really important to me._

These examples illustrate how video calls provided opportunities to continue care practices that would ordinarily be conducted face to face and that might have been difficult or impossible when in-person visits were restricted.

**Theme 2: The Role of Video in Extending Care**

This theme responds to our initial question of how video calling was beneficial to family members, that is, how specific qualities associated with using video calls contributed to the continuation of care. This means emphasizing the value that video calls add to care—not just how video calls contributed to the continuation of care but how they enhanced care as well.

### “I Get to Speak to Her More Than Before”: Video Calls Enabled Increased Frequency of Contact

The availability of video calling enabled some participants to contact their relatives more frequently after the pandemic began. Several participants (8/18, 44%) lived far from their relatives’ care homes and, hence, incurred substantial costs when visiting. These participants described visiting once per week or several times per month before the lockdowns. The transition to video calling allowed these participants to “visit” more frequently than before. Olive, for example, commented on how the frequency of contact with her great-aunts had increased after the lockdowns and how it involved extended family members:

_In terms of frequency, I would visit once a month on a Sunday [before the pandemic]. During COVID we would FaceTime once a week...That was done as a family, as well. We would have two- or three-way conference calls._

Although face-to-face visits were still preferred, the ability to be in more frequent contact was important to those who were concerned about their relative’s health. Ben, for example, valued the ability to pay more attention to his father when there was an outbreak of COVID-19 at his facility. However, some participants (2/18, 11%) mentioned that facilities had discontinued support for video calling when the lockdowns were lifted as they viewed it as nonessential. These individuals wished that video calling had continued so that they could maintain the increased frequency of contact. Gloria, for example, commented on the inconsistent availability of video calling at her husband’s facility:

_Once lockdown is over, that’s the end of the video calls and it would be so much better if they could keep it going. And then, I could just touch base with him every day to see how he’s going and he knows that I’m there and caring for him._

This extract speaks to frequent contact as a means for families to convey the sense that the resident is being cared for. Although increasing the frequency of contact does not guarantee higher-quality interactions [62], our participants’ experiences speak to the value of having a communication channel available and highlight the importance of being able to contact a family member during times of distress.

### “It’s Crucial for Us to See Him”: Video Provided Access to Nonverbal Cues

Many participants’ experiences stressed the importance of the visual layer associated with a video call. Being able to see the resident is a key differentiator between video and other communication technologies such as the telephone.

We interpreted participants’ experiences as signaling the importance of nonverbal cues for the continuation of care. Such cues include gestures and body movements, facial cues such as lip and eye movements, and the tone of voice. Previous work has argued that nonverbal cues contribute to the “richness” of video calls and enhance feelings of social presence [30,57,63], which refers to the salience of the other person in the interaction [64]. Higher social presence is thought to promote a sense of togetherness when using video calls [18,59].
Our analysis of participants’ experiences suggested that transmitting nonverbal cues played other roles in providing care. First, nonverbal cues were crucial for participants whose relatives had severe communication impairments. These people emphasized that it was essential to see their relatives when communicating with them, which made video calling more helpful than modalities such as the telephone. As an example, Charmaine discussed how nonverbal cues were crucial for interacting with her father, who had become largely mute because of progressive supranuclear palsy. She said the following:

...he will mouth words, but he doesn’t generally speak out loud and he has trouble finding his words. So we’ve really found that video conferencing works best so you can get the non-verbal cues.

When asked to elaborate on what kinds of cues are important and how they help, Charmaine said that nonverbal cues were useful for the following:

...being able to see that he’s thinking, because you can see where he’s looking often...And I guess we’re getting better at reading his body language too. He tends to nod, or shake his head, or mouth the words “no” or “yes,” or he’ll just shrug. We also prompt him to speak out loud which used to work more effectively than it does now. But sometimes he can come up with a sentence, and I’ll put my hand up. So I’ll use nonverbal cues as well, like putting my hand up [to show] that I can’t hear.

Charmaine’s quote points to the role of eye gaze direction, speed of response, and body language when conversing with her father. It also reveals that the utility of nonverbal cues is bidirectional, with Charmaine using her own gestures to convey information back to her father. These interactions illustrate the complexities of communicating with people living in aged care and highlight the additional value that video-mediated exchanges brought during the lockdowns.

A second role of nonverbal cues was to support the conveyance of warmth and affection during emotive communication. Deborah recalled the importance of gestures when interacting with her mother, who has dementia:

Gesture communication is very important, especially being Italian. When on the video call, we send kisses to each other, not only at the end, but during the communication itself. I always try to smile to her, she recognizes it. Sometimes I sing songs to her. So it’s not only verbal communication but many other things. I showed her a soft toy and she started laughing. It was funny, she reminded me of a little girl smiling to a doll. It works, somehow, I feel that she is there. She is in a connection with me, a member of the family again.

The importance of nonverbal cues also came to the fore when discussing the widespread use of face masks during the pandemic. Several participants (6/18, 33%) were able to visit their relatives in between periods of lockdown, when bans on visitors were lifted temporarily. These visits required the use of face masks to comply with government regulations. Participants reported that masks made conversations difficult as they occlude facial cues that can underpin nonverbal communication. Masks also made it difficult for residents to understand what was being said, especially among those who were hard of hearing. The fact that video calls did not require masks was said to make conversations “closer to normal.” For example, Elaine told us the following:

One difference between face to face and video is that we are not wearing our masks on video calls. When we go there we have to wear a mask in person. So we have these face shields, and that means it is more natural on video calls. It doesn’t seem like there is so much of a barrier, even though we’re not physically there, it just feels like a barrier, a perceived barrier, when we are wearing masks.

Taken together, the availability of nonverbal cues can be seen as making a video call feel more like a physical visit compared with wearing a mask or using a modality such as the telephone.

### Theme 3: Organizational Constraints Threatened the Continuation of Care Through Video Calling

This theme brings together organizational issues that negatively affected participants’ use of video calling. Our interpretation is that these issues were problematic as they hampered participants’ ability to enact continuation of care.

**“There’s Problems With the Connection There”: Video Calling Was Hampered by Limited Technology Infrastructure**

Consistent with prior work [33,34], the lack of high-quality technology infrastructure in care homes was a problem with video calls. Participants reported that their relative’s aged care facility did not have reliable internet. This led to mixed experiences and unpredictable call quality. Margaret shared the following:

Some weeks, we’ll have a beautiful conversation and it doesn’t drop out at all. Then, more often, we’ll have parts of the conversation where we freeze or they freeze. Sometimes they drop-off completely.

These connectivity problems led to anxiety and stress for residents and sometimes caused them to think that they had “broken” the technology. Participants described having to spend time reassuring relatives in this situation and had to fix technical problems over the telephone. This was not always easy without the ability to visit in person.

In addition to the lack of stable connections, it became apparent that many homes had a limited pool of technologies available to support video calls. Katherine, for example, said that her mother’s aged care home had “only one iPad for 63 families.” This meant that video calls were sometimes cut short as the device was needed for other residents. In some cases, staff members tried to overcome this problem by loaning their personal devices to residents. However, it seemed that the loaning of devices further increased the likelihood of calls being cut short. Robin, who had been using video to see her
grandmother, felt that this made some video calls “rushed and inauthentic.” She said the following:

…the worst part is when they cut you off...if they use their personal phones, it’s like, “Oh, sorry, I have to take this, there’s something urgent I need the phone for.”

We interpret these experiences as limiting participants’ ability to carry out actions relevant to continuing care. That is, poor connections and rushed calls impeded the ability to continue care by providing insufficient information about the residents’ well-being.

“lt Was Like Calling a Prison”: Video Calls Had to Be Booked in Advance

A putative benefit of video calling is that family members can potentially make and receive calls at any time and at their own convenience. However, the interviews revealed that this benefit was not realized for all participants. Instead, the lack of technology in some homes meant that video calls had to be scheduled in advance. This was done using booking systems created from an assemblage of web-based calendars, email, and telephone. There were also cases where video calls were available only during restricted “visitation hours”—such as at fixed times in the morning, afternoon, and evening. This meant that participants had to schedule their days around these windows, and if they could not be available at the specific time, they were not able to see their relatives.

The need to schedule calls was a repeated source of frustration and became a barrier to continuing care. Nicole, for example, described it as “a pain” and wished video calls could be used similarly to telephone calls as “they [the home] allow you to ring anytime.” The restrictions around call times, together with the lockdown conditions in care homes, were described as creating a “prison-like setup.” Irene said that the following occurred during one of the lockdowns:

You could not ring anybody in the facility, nor the front desk. It was like a prison, they had one number you could ring and then you could organize something and so you would send an email and say, “Can I have the appointment to Zoom at this time?” And if that one worked, then we could say, “Same time tomorrow, please.” And they’d pencil it in.

Despite participants’ attempts to work around the schedules imposed by the care homes, there were cases in which prearranged calls were late or failed to materialize, causing frustration. Gloria told us the following:

[the home] might set up a time, but they’re never on time. So, you have to be available for, let’s say, a frame of two hours. I keep telling myself, just be patient.

Finally, there was considerable variation in the duration and frequency of calls. Gloria stated that one lockdown involved “two calls a week set up by the staff, but five-minute duration,” whereas Alison said that calls lasted “half hour or a 15-minute session.” These calls were the only source of outside social contact for the residents. Although these short calls may be better than no contact at all, they should raise questions about the adequacy of solutions provided during the pandemic and how these might be improved in the future.

“The Staff Are Flat Out Now”: Staff Involvement Was Needed but Was Often Scarc

Consistent with prior work [36,37], participants raised the need for staff to sometimes assist residents with video calling. Staff were involved in making calls, manipulating the hardware and software, and fixing technical issues. Staff were seen as essential for supporting video calls with residents who had complex care needs, especially those living with dementia. In this case, staff were needed for actions such as directing the resident’s attention to the call, explaining who the resident was talking to, and repeating phrases and words if residents could not hear the video call properly. However, staff were reported to be time-pressured and not always available to assist with these activities.

The need for staff involvement was especially challenging during the COVID-19 lockdowns because of staff shortages and outbreaks within the aged care sector [65]. Some participants (5/18, 28%) felt that staff turnover was a problem that affected video calling. These individuals had developed co-operative relationships with specific staff members. Video calls were reported to be difficult or impossible when these staff members were absent. For example, Ben said the following:

Like most aged care facilities, they’re at their capacity to provide health assistance. And so it took a while to identify a couple of the nursing staff who both are willing and can find the time to actually help him do calls. And so far, the only ones we’ve been able to do is when I’m calling him and they answer for him.

Theme 4: Successful Continuation of Care Required 2-Way Communication

This final theme highlights 2 issues that further impeded continuation of care but that focus on the need for the people in aged care to be able to use and respond to video calls.

“She Was Never What You Would Call Tech-Savvy”: Some Residents Unfamiliar With Video Calls

Some participants (6/18, 33%) stated that their relatives in care were unfamiliar with video calls and had received no training on how to use them. This was a challenge as their relatives did not know how to operate the software and hardware independently, meaning that calls failed to happen or went unanswered.

Participants also mentioned that their relatives did not always understand the concept of positioning oneself in the camera feed. This led to situations in which the participants saw their relatives from awkward angles or without their faces in the frame. Gloria said that her husband did not understand how to manipulate the iPad provided to him at the care home. She recounted the following:

[He] just never had anything to do with computers or really technology at all. He didn’t get the concept that you can see yourself on the screen if you’ve got it aimed correctly. That made it rather difficult.
To overcome this problem, Gloria and other participants noted that staff involvement was needed. However, as noted previously, this was not always possible. She said the following:

"The staff often go away and leave him, and I would end up looking at the ceiling because the iPad would fall over or something like that, and all I could see was the ceiling."

This challenge can be interpreted as further affecting participants’ ability to continue care, especially in monitoring health. This is because the underlying concern relates to acquiring visual cues; when the camera is not angled correctly, it becomes impossible to make inferences about the residents’ welfare.

**“For Her, This Could Be a Broken Mirror”: Residents’ Health Conditions Make Video Calls Challenging**

Many people in aged care are living with profound health challenges, some of which precipitate their move into care [66,67]. Participants reported that residents’ health problems affected their ability to participate in video calls, often because commercial systems are ill-suited to the aged care setting [35] and require adaptation to be successful [61].

For example, Paul discussed how his grandmother had arthritis in her hands, making it difficult for her to use computers for video calls. To overcome this issue, Paul and his family purchased a large-screen smartphone and “jacked up the size of the keyboard” to make the device more usable for her. More challenging cases were reported by participants whose relatives had moderate or advanced dementia. Some (4/18, 22%) stated that, although video calls were valuable for checking on their relative’s well-being, the conversation was limited as the relative did not fully understand the nature of video calling technology. Our first participant, Alison, had been using video calls to see her mother but decided to abandon them as her mother could no longer comprehend what was happening. She said the following:

"Sadly, because my mum had dementia, she couldn’t actually use the technology. It didn’t work for her, so we essentially got cut off from her for 18 months. In that way, they made it an option, but it wasn’t an option for someone with [advanced] dementia."

When asked to elaborate on why the technology “didn’t work,” Alison discussed how her mother became confused when seeing an image of herself on screen, which is a common feature of video calling applications such as Skype and Zoom. Alison said the following:

"My mother couldn’t understand what was going on. She wouldn’t interact with it. She wouldn’t look at the screen. If she saw herself on it, she’d just be staring and trying to figure out who that person was. She was better at engaging in person."

This example highlights that, although family members may still obtain some benefits from seeing relatives through a video feed, different approaches may be required to enable families to continue seeing residents who have advanced care needs during times of social distancing.

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**Discussion**

**Principal Findings**

This study aimed to understand family members’ uses of video calling during lockdown restrictions in aged care. The main finding of our analysis was that video calling became a medium for family members to enact the continuation of care during lockdown restrictions. Although participants’ experiences of video calling were complex and multifaceted, there was an underlying goal of using the technology to continue care and ensure that care was provided. However, the use of video calls was affected by organizational constraints and the need for 2-way communication with relatives, which was often difficult. These findings contribute to an improved understanding of why video calls were valued during the pandemic lockdowns and extend the knowledge of the challenges that families encountered [33].

Previous research on the use of video calls in aged care has focused primarily on the potential to support social interaction and the technological barriers that can affect their use. Our study is the first to suggest that video calling systems are used for the continuation of care when families cannot visit the facility. This interpretation moves beyond existing characterizations of video as a tool for social connectedness [27] to one in which video calls are used to continue care practices when physical visits are restricted. Many of the activities conducted by participants in this study, including relational maintenance and health monitoring, align with the findings of ethnographic studies on the coordinated work of families in care homes [67]. Our analysis suggests that, when video calls were used to replace in-person visits, they became a modality for families to continue these contributions to care. However, they can also enable new kinds of interactions, such as sharing digital content over distance and supporting meetings with extended family. This speaks to the potential for video to enrich caregiving in ways that go beyond what is possible in a face-to-face visit.

This study also suggests that video calling supports family members’ own peace of mind. The COVID-19 pandemic was an extremely stressful time for families, and it has been suggested that the inability to visit during lockdowns produced feelings of helplessness and anxiety [9]. Concerns about residents’ health may have been especially salient given the high rates of mortality in aged care [65], leading family members to request more frequent updates about residents’ welfare [11,68]. However, video calling can convey information that provides peace of mind without placing additional burden on staff members to provide such information. This raises the importance of video calling from a platform of conversation to one that can enhance care in multiple ways, emphasizing the need to improve provision of video calls and develop solutions that are better suited to the aged care context. Our findings highlight the urgent need for video calls to be seen within the aged care sector not just as a secondary means of providing social support but also as a vital tool that allows families to contribute to the ongoing care of their loved ones.

In addition to continuing care, our analysis indicates that video calling can enhance family members’ caring practices when...
forced to see their relatives from a distance. When video calling worked well, participants were able to have more frequent contact than before and were able to access nonverbal cues that were essential for communicating with residents who had impairments. This finding is important as, in some countries, care homes are mandated to provide telephone communication with relatives [13], but video calling is an optional extra. Providing better support for video calling can help families whose relatives have hearing and speech impairments and who depend on gestures and lip movements to understand what is being said. This also speaks to the value of supporting video calling outside of lockdown periods for family members who cannot easily visit the care home [28,58].

Finally, our analysis identified that the continuation of care through video calling was impeded by multiple challenges. One problem relates to the constraints of the aged care context, where homes are often underresourced and understaffed [67]. This was especially challenging during the pandemic [65] and influenced the quality, reliability, and length of video calls. Residents’ unfamiliarity with video calling and their health problems were additional barriers that affected the success of video calls [35,37]. Given the important role that video calls can play in the continuation of care, addressing these challenges can no longer be seen as a secondary concern that is relegated to the periphery of lifestyle programs but must be seen as central to supporting the ongoing welfare of aged care residents.

Comparison With Prior Work

The notion of video calling as a medium for the continuation of care aligns with ideas from early studies that used videophones, which were a primitive form of video calling technology. Demiris et al [60] suggested that videophones could support “distant caregiving.” Our work substantiates and adds weight to this claim by showing how the high-fidelity feeds of modern systems can be used in the practice of continuing care. We also emphasize the ability of video to support caregiving during periods of lockdown, which may become more common in the future if COVID-19 becomes endemic [22] and because of seasonal variation in other viral diseases [69].

The challenges identified in this study align with findings of previous trials of video calling in aged care. Examples include limited technology literacy among some residents, low device accessibility, poor Wi-Fi, the lack of devices in care homes, and the need for staff to help with video calls [30,34,35]. In addition, our findings resonate with a study conducted in Canada during the COVID-19 pandemic [33]. Similar to our work, the Canadian study found that care homes had very few devices to facilitate video calls, that video calls were often missed and late, and that staff lacked time to help with facilitation [33]. Taken together, these findings suggest that there are systemic issues in aged care that need to be addressed to better support video calls and the crucial role they play when in-person visits are not possible.

A novel finding of this study was that resource constraints required care homes and families to coordinate call times using booking systems, which may have also helped ensure fair and equitable access to limited devices. However, this coordination was effortful for family members and led to unsatisfying interactions when calls were late or missed. It is likely that this issue was not documented in previous studies as they did not examine the use of video calling during periods of lockdown. This addition to the literature is important as it reveals a negative experience for families and residents that should be avoided during future lockdowns in care homes.

Implications for Video Calling in Aged Care

This study highlights that ongoing support for video calling in aged care is essential. We argue that video calling should, therefore, be elevated to the status of critical infrastructure given its potential to enable the continuation of care and mitigate the negative consequences of enforced isolation.

However, video calling needs more infrastructural support in care homes. It must be recognized that social connection is an essential human right and must be supported as a basic activity. Policy makers should recognize that staff may need additional time to assist with video calling. Better resourcing is needed for technologies that can be shared among residents at times when face-to-face visits are not possible, and aged care workers should not have to use their own devices to support the social well-being of residents.

The problem of coordinating video calls between families and residents should also receive attention in terms of improving residents’ freedom to make and receive calls during lockdown. If video calls are used at times when in-person visits are prohibited, there is a need for care providers to consider ways of ensuring that calls can happen on a regular basis and to support interactions that go beyond mere glimpses of the resident. Although short video calls may be better than no contact at all, they are unlikely to constitute sufficient social contact and can create anxiety among families. This can also be seen as an equity issue in that being able to see a loved one should be a right, not a privilege.

Improving the design of video calling systems for aged care can also help lower the burden placed on staff when it comes to administering and running video calls. Our findings reiterate that commercial video calling systems can be hard to use for care home residents [35,59]. To provide a suitable user experience, future designs should aim for the ease of use, learnability, and accessibility of software, especially for those with dexterity impairments [70,71]. Video calling hardware could also be made more suitable for aged care, such as by using physical stands or supports that enable residents to maneuver the video calling device into a comfortable position without needing substantial involvement from caregivers [61]. An ideal video calling system for aged care would be accessible and support independent use, incorporating software that is easy to understand and hardware that can be positioned according to the resident’s needs. This, in turn, would reduce the need for staff involvement.

Strengths and Limitations of This Study

This study has 2 main strengths. First, our analysis is grounded in real-world experiences of video calling deployment during lockdowns. This is different from most previous studies, which typically involved participants who were given a technology to trial by a research team [28,31,32,66]. Our findings reflect the
experiences of families and care homes who had to manage the technology by themselves during unexpected and indeterminate periods of lockdown, evidencing the issues that arise in this situation.

The second strength of this study lies in our focus on close family members, many of whom played an important role in caring for their relatives. Previous studies have often been designed to test the feasibility of using video calls to initiate connections with family members who do not typically visit the home (eg, distant grandchildren who play no substantial caring role [28]). Our work expands the scope of the literature to provide an understanding of why video calls are valuable to family members who play considerable caring roles.

The main limitations of this study are 2-fold. First, the focus on family members does mean that we excluded the views of aged care residents and staff on video calling during periods of lockdown. We were not able to interview these groups as care facilities were inaccessible during data collection. Future research should address this gap. Second, this study focused solely on the experiences of people living in Australia and New Zealand. Aged care systems in other countries may have procedures in place to better support video calling during lockdowns, although as we have noted, a Canadian study highlighted similar concerns [33]. Future studies that compare video call experiences in diverse aged care contexts and in other countries are warranted.

Finally, trustworthiness is an important consideration when evaluating the credibility of qualitative research [58], but there is an open question as to what makes RTA trustworthy. We consider our analysis trustworthy as it matches well with guidance for producing trustworthy thematic analysis [57] and for high-quality reflexive analysis [45]. Examples of practices that evidence trustworthiness in our approach include a clear rationale for using RTA [45], prolonged engagement with the data [72], and full disclosure of our analytic process [57] (Multimedia Appendix 2). To improve our practice in the future, we recommend using a reflexive journal to document the analytic process [73] and create an audit trail [57].

Conclusions
This study investigated how family members used video calls with older adults in residential aged care during lockdowns arising from the COVID-19 pandemic. Overall, our findings suggest that video calls were used by family members to continue care practices at times when face-to-face visits were not possible. Families were able to provide social enrichment and monitor the residents’ health and well-being, which they could then use to ensure continuity of care. Video calls extended care by enabling frequent contact and were crucial for those who were reliant on nonverbal cues for communication, sometimes making them preferable to physical visits in which masks were required.

However, this study shows that family members’ ability to engage in the continuation of care was hampered by organizational issues, particularly the lack of digital technology in aged care. Although this can be partly attributed to the speed at which care homes needed to adapt and to the loss of staff during the pandemic, the situation revealed the paucity of support for video calling in many care homes. If video calls are to be used to mitigate social isolation arising from infection control measures, there is an urgent need for better provision of technology and improvement of infrastructure to enable calling. There may also be a need to allow for staff to support video calling, especially for residents who cannot operate the technology independently.

To conclude, our findings emphasize that governments and aged care providers should fully support the implementation of video calls between residents and their family members during times when social distancing is required. This study also reiterates the need for video calling solutions that are better suited to aged care such that families can remain connected with residents even when they are forced to be physically apart.

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Data Availability
The data sets generated and analyzed during this study are not publicly available as ethics approval was not given for the data to be made public. Requests to access the data sets should be directed to RMK. The data may be made available upon reasonable request.

Authors’ Contributions
RMK and JW conceived and designed the study. RMK collected the data and conducted data analysis. RMK drafted the manuscript. YX, SB, and JW provided comments, edits, and suggestions. RMK revised the manuscript in response to reviewers’ comments. SB, YX, and JW provided feedback and made additional revisions. All authors provided input for the final version of the manuscript.

Conflicts of Interest
None declared.
Multimedia Appendix 1
Interview questions used in the study.

[DOC File, 31 KB - aging_v6i1e40953_app1.doc]

Multimedia Appendix 2
List of techniques used to establish trustworthiness in our analysis based on the Means of Establishing Trustworthiness by Nowell et al [57].

[DOCX File, 17 KB - aging_v6i1e40953_app2.docx]

References


63. Teo AR, Markwardt S, Hinton L. Using Skype to beat the blues: longitudinal data from a national representative sample. JMIR Aging 2023 | vol. 6 | e40953 | p.45https://aging.jmir.org/2023/1/e40953
Review

Digital Intergenerational Program to Reduce Loneliness and Social Isolation Among Older Adults: Realist Review

Jie Kie Phang¹²*, BSc, MPH; Yu Heng Kwan¹²³, BSc, MD, PhD; Sungwon Yoon¹², MPH, PhD; Hendra Goh², BSc, MPH; Wan Qi Yee⁵, BSc; Chuen Seng Tan⁶, BSc, MSc, PhD; Lian Leng Low¹⁵⁷⁸⁹, MBBS, MMed, MCI

¹Centre for Population Health Research and Implementation, SingHealth Regional Health System, SingHealth, Singapore, Singapore
²Health Systems and Services Research, Duke-NUS Medical School, Singapore, Singapore
³Department of Pharmacy, National University of Singapore, Singapore, Singapore
⁴Internal Medicine Residency, SingHealth residency, Singapore, Singapore
⁵Population Health & Integrated Care Office, Singapore General Hospital, Singapore, Singapore
⁶Saw Swee Hock School of Public Health, National University of Singapore, Singapore, Singapore
⁷Department of Family Medicine & Continuing Care, Singapore General Hospital, Singapore, Singapore
⁸SingHealth Duke-NUS Family Medicine, Duke-NUS Medical School, Singapore, Singapore
⁹Outram Community Hospital, SingHealth Community Hospitals, Singapore, Singapore
* these authors contributed equally

Corresponding Author:
Yu Heng Kwan, BSc, MD, PhD
Health Systems and Services Research
Duke-NUS Medical School
8 College Rd
Singapore, 169857
Singapore
Phone: 65 90231226
Email: phakyh@nus.edu.sg

Abstract

Background: There is a compelling need for an innovative and creative approach to promote social connectedness among older adults to optimize their well-being and quality of life. One possible solution may be through a digital intergenerational program.

Objective: This realist review aimed to identify existing digital intergenerational programs that were used to reduce loneliness or social isolation among older adults and analyze them in terms of strategy, context, mechanisms, and outcomes.

Methods: We performed a realist review with an extensive search of published and gray literature. For scholarly literature, we searched PubMed, Embase, CINAHL, PsycINFO (Ovid), and Social Sciences Citation Index databases for articles published between January 2000 to August 2020. A grey literature search was performed using the Google search engine, and the search was completed in May 2021. We included programs that evaluated digital intergenerational programs for older adults, which described outcomes of loneliness or social isolation. We included quantitative, mixed methods, and qualitative studies, as well as relevant theoretical papers, policy documents, and implementation documents. The studies were appraised based on their relevance and rigor. We synthesized the available evidence from the literature into Strategy-Context-Mechanism-Outcome (S-C-M-O) configurations to better understand what, when, and how programs work.

Results: A total of 31 documents reporting 27 digital intergenerational programs were reviewed. Our final results identified 4 S-C-M-O configurations. For S-C-M-O configuration 1, we found that for community-dwelling older adults, provision of access to and training in digital technology may increase older adults’ self-efficacy in digital devices and therefore increase the use of digital communication with family. In S-C-M-O configuration 2, digital psychosocial support and educational interventions from nurses were found to be useful in reducing loneliness among community-dwelling older adults. In S-C-M-O configuration 3, a video call with a student or family was found to reduce loneliness among older adults residing in long-term residential care facilities. Finally, for S-C-M-O configuration 4, we found that behavioral activation provided through videoconferencing by a lay coach may be useful in reducing loneliness among older adults who are lonely. However, as almost half (11/27, 41%) of the included programs only reported quantitative results, this review focused on screening the discussion section of publications to identify author opinions or any qualitative information to elucidate the mechanisms of how programs work.
Conclusions: This review identified the key strategy, context, and mechanism influencing the success of programs that promote intergenerational interaction through digital means. This review revealed that different strategies should be adopted for different groups of older adults (eg, older adults who are lonely, older adults who reside in long-term residential care facilities, and community-dwelling older adults). The S-C-M-O configurations should be considered when designing and implementing digital intergenerational programs for older adults.

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KEYWORDS
-aged; loneliness; older people; review; social isolation

Introduction

Background

Driven by decreased fertility rates and increased life expectancy, worldwide population aging is expected to continue [1]. The number of people aged 65 years or older is projected to grow from an estimated 524 million in 2010 to nearly 1.5 billion in 2050, representing around 16% of the total world population in 2050 [2]. Loneliness and social isolation in older adults affect a significant proportion of older adults worldwide, with current estimates of the extent of loneliness among older adults living in the community to be around 50% [3], and around half of people aged >60 years are at risk of social isolation [4]. Loneliness and social isolation pose serious public health risks as they are associated with adverse health outcomes [5,6]. Loneliness may be associated with higher blood pressure, worse sleep, immune stress responses, and worse cognition over time in older adults [7]. A meta-analysis demonstrated that social isolation among older adults significantly increases the likelihood of mortality, and its influence on mortality risk is comparable with well-established risk factors such as smoking, obesity, and physical inactivity [8].

One possible solution to mitigate loneliness and social isolation among older adults may be through an intergenerational program that leverages digital technology [9]. An intergenerational program can be defined as “vehicles for the purposeful and ongoing exchange of resources and learning among older and younger generations for individual and social benefits” [10]. Intergenerational programs can strengthen connections among different age groups and promote organized shared experiences, which may enhance the health of older adults by decreasing the risk of loneliness and social isolation [11-13]. An added advantage of intergenerational interaction over peer interaction is that it provides younger generations with an opportunity to break down agist stereotypes [14], which will help in strengthening community cohesion [15]. Previous reviews have demonstrated the advantage of intergenerational interaction over peer interaction, including allowing younger counterparts to develop new communication skills and improved perceptions toward older adults [9,13,16]. In fact, the Decade of Health Ageing by the World Health Organization has emphasized the need for intergenerational solidarity [17]. Intergenerational programs are usually conducted face to face, and some examples include conducting home visits or organizing large-scale events involving people from different age groups [13,18]. Although there are systematic reviews available that summarize the interventions for reducing social isolation and loneliness in older persons [19-22], these reviews did not focus on intergenerational programs.

During the COVID-19 pandemic, social isolation among older adults intensified with the implementation of social distancing measures [23-26]. Therefore, using digital technology such as video calls to achieve intergenerational bonding becomes more compelling considering the social distancing measures implemented worldwide [27]. The other advantages of digital intergenerational programs in combating loneliness and social isolation among older adults are their ability to connect and reconnect people across large geographic distances, and their support for both synchronous and asynchronous forms of communication [28]. Current reviews of intergenerational programs are primarily based on face-to-face interventions [29-31], with a lack of emphasis on digital interventions. Although there is a scoping review by Reis et al [32] on technologies that foster intergenerational connectivity and relationships, it did not provide an analysis of program outcomes.

In addition, previous traditional reviews tend to predominantly focus on whether the intervention “worked,” often without an understanding of the complexity of the intervention in terms of for whom they may or may not work, under what context and mechanism [33]. The realist review methodology used in this study seeks to provide an explanatory analysis aimed at discerning what works for whom, in what circumstances, in what respect, and how [34]. The emphasis on strategies, contexts, and mechanisms in our realist review can provide an in-depth understanding of how and why interventions are successful or unsuccessful [22,35], which is lacking in existing reviews on intergenerational programs [29,31]. In addition, as studies on intergenerational programs are unlikely to be randomized controlled trials, a realistic review looking at strategy, context, mechanisms, and outcomes will be more appropriate.

Objective

This review aimed to identify existing digital intergenerational programs used to reduce loneliness or social isolation among older adults and analyze them in terms of strategy, context, mechanisms, and outcomes. The findings of this study will inform the design and implementation of digital intergenerational programs to reduce loneliness or social isolation among older adults.
Methods

Overview

Our review followed the realist synthesis principles recommended by Pawson and Tilley [36] and was anchored on the Realist And Meta-narrative Evidence Synthesis: Evolving Standards criteria [37]. In this review, we used the Strategy-Context-Mechanism-Outcome (S-C-M-O) configuration (Figure 1) as this review aimed to understand which digital intergenerational program strategies have been implemented and why some of these strategies were successful [38]. Therefore, the strategies were explicitly identified, along with the context in which they were implemented, the mechanism that was triggered, and which outcome was consequently generated [39]. In this review, we focus on the target population, settings, and counterparts under the context. This S-C-M-O configuration has also been adopted in other realist reviews [40,41].

Evidence Search

We performed a systematic review of the scholarly and gray literature. We searched the PubMed, Embase, CINAHL, PsycINFO (Ovid), and Social Sciences Citation Index databases for articles published between January 2000 to August 2020. Although intergenerational programs have existed for many decades, most empirical studies assessing the influence of intergenerational interactions on health-related outcomes in older adults have been conducted since 2000 [30,42]. The search in the electronic databases was performed on September 17, 2020. A search strategy with 3 components (ie, “elderly,” “digital communication,” and “intergenerational relationships”), which was devised in collaboration with an information specialist librarian, was utilized (Multimedia Appendix 1). The search filter of the English language was applied when available to minimize potential information loss during the translation process. We downloaded the search records into Endnote and duplicates were removed. A gray literature search was performed using the Google search engine with “intergenerational and digital” search strings. All 197 results from the Google search engine were screened, and the search was completed on May 2, 2021. Snowball searching was used to identify additional articles based on the reference lists of the included studies and relevant systematic reviews.

Two members of the study team (JKP and HG) independently screened all identified articles. For the scholarly literature, a 2-stage screening process was used where title and abstract were reviewed in the first stage, followed by a review of full-text articles in the second stage. The disagreement rates between the 2 reviewers were 0.14% (6/4382) and 0.9% (2/226) at the title or abstract and full-text screening stages, respectively. For gray literature, the entire document was reviewed because of a lack of executive summary or equivalent in some documents. Any discrepancies in article eligibility were discussed with a third reviewer (YHK) until consensus was reached.

Quantitative, qualitative, and mixed method studies were included. Studies met the inclusion criteria if they described 2-way digital interaction involving older adults with nonfamilial younger generations or with family, were written in English, were evaluative, and described outcomes of interests including loneliness, social isolation, or other related concepts such as social participation and social connectedness. These outcomes are selected given the lack of consistent definition of social isolation in the literature [43] as well as the interchangeable use of “loneliness” and “social isolation” in literature [43]. As there are various definitions of the age range of “older” populations [32,44], a cutoff for the lower age limit was also not specified. As such, we included programs that identified themselves as focusing on older adults or grandparents [32]. The nonfamilial younger generation was defined as either being 30 years old or younger for nonfamily members based on criteria from a previous review [31]. In cases where the characteristics of the intergenerational counterparts were unclear (eg, age of the nurses or coaches involved in communicating with older adults were not clearly described), we contacted the corresponding author to clarify, and only included programs where the counterparts (eg, nurses and coaches) were aged 30 years old or younger. We excluded programs (n=3) [45-47] where the corresponding author did not respond. However, because of the small number of programs focusing solely on digital intergenerational communication (n=1) after an initial review of the literature, we included programs that allow both intergenerational and nonintergenerational digital communication (eg, peer communication). For the familial intergenerational program, we included programs that described digital interaction with family in general, as most of the quantitative studies did not specify the types of digital familial interaction, and this allows a more comprehensive view of the programs available for digital intergenerational communication. More importantly, studies have demonstrated that similar programs are likely to increase contact with younger generations such as children and grandchildren who are well versed with digital technology [48,49]. Descriptive, nonevaluative articles were also included if they were related to a program that had been formally evaluated and included in the review. Articles that were not
program specific (eg, commentaries or discussion papers) were excluded.

**Data Extraction and Appraisal of Studies**

Relevant information from the documents was extracted using a data extraction template. The studies were appraised based on their relevance and rigor. Relevance was defined as the level of contribution to the review, and rigor was defined by the methodological quality of a study conducted on a digital intergenerational program. Relevance was assessed by reviewing the details provided for (1) context (eg, user, program features, or design components), (2) mechanism: hypotheses as to how specific strategy worked or did not work, and (3) outcome: reasons for effect or lack of effect on outcomes related to loneliness or social isolation. These details were obtained by reviewing the documentation of usability evaluation, program or study protocols, and publications related to evaluations (eg, clinical intervention studies evaluating efficacy or effectiveness). In programs where authors did not describe how they thought their program worked or did not work, this was inferred by the study team after careful reading of the description of the program. The relevance was rated as low (little or no information), medium (some information), and high (well-described information). The criteria for assessment of relevance were adopted from a previous realist review [33], in which “strategy” was considered in the mechanism section. The methodological quality of evidence (rigor) around each therapy was assessed using the Mixed Methods Appraisal Tool (MMAT) [50]. The MMAT assesses the quality of qualitative, quantitative, and mixed methods studies. It focuses on methodological criteria and includes five core quality criteria for each of the following five categories of study design: (1) qualitative, (2) randomized controlled, (3) nonrandomized, (4) quantitative descriptive, and (5) mixed methods.

**Evidence Synthesis**

We examined the strategy, context, mechanism, and outcome in each program and looked for recurrent patterns of outcomes and their associated strategies, contexts, and mechanisms. We concentrated on what appeared to be recurrent patterns of contexts and outcomes in the data and then sought to explain them through the strategies and mechanisms by which they occurred. The proposed S-C-M-O configurations were analyzed at different levels of abstraction (within and across programs) to determine the most robust and plausible explanations of how, in a context, with the strategy and mechanism, the outcomes observed could be generated. The evaluation of relevance and rigor was considered when generating and revising S-C-M-O configurations. The initial list of S-C-M-O configurations was revised based on the consensus between study team members, based on the synthesis process recommended by Pawson [51], including synthesis to adjudicate between rival program theories and synthesis to consider the same theory in comparative settings.

**Results**

**Overview**

Figure 2 presents a flow diagram outlining the evidence-based search process. We retrieved 5791 records from the scholarly literature search of 5 databases (PubMed, CINAHL, PsycINFO, and Social Sciences Citation Index databases). After removing duplicates, a total of 4382 unique and potentially eligible documents were reviewed for inclusion. We excluded 4156 records and 201 documents at the title or abstract and full-text screening, respectively. The reasons for exclusion at the full-text screening stage can be found in Multimedia Appendix 2. We added 4 documents from the snowball searching method based on the reference lists of already included studies and relevant systematic reviews. In addition, we also retrieved 2 relevant documents from the grey literature search using the Google search engine. In total, 31 documents from the scholarly and grey literature search detailing 27 unique digital intergenerational programs were included for synthesis in this realist review.
Structure and Delivery Features

Table 1 presents an overview of the structure and delivery features of the 27 programs. A total of 10 programs were for older adults residing in long-term residential care [52] (including nursing home [53-55], retirement homes [56], aged care facilities [57], assisted living retirement facilities [58], social housing [59], care homes [60], and veterans’ care facility [61]), 16 programs for community-dwelling older adults [62-75], and 2 programs included both community-dwelling older adults and older adults residing in long-term residential care facilities [48,76]. Only 1 program (StoryBox) was designed for exclusive digital intergenerational interactions [70]. Most (8/27, 30%) programs were conducted in the United States [53,58,60,66,72,74,76,77].

Figure 2. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.
Table 1. Structure and delivery characteristics of digital intergenerational program.

<table>
<thead>
<tr>
<th>Program, country</th>
<th>Participants</th>
<th>Program detail</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (years)</td>
<td>Older adults, n</td>
</tr>
<tr>
<td>ACTION [62], Norway</td>
<td>57-85</td>
<td>19</td>
</tr>
<tr>
<td>ACTION (redesigned) [63], Sweden</td>
<td>66-85</td>
<td>8</td>
</tr>
<tr>
<td>ACTIVE [52], Norway</td>
<td>Mean 78.3 (SD 12.5)</td>
<td>15</td>
</tr>
<tr>
<td>AGES 2.0 [48], United Kingdom</td>
<td>60-95</td>
<td>53</td>
</tr>
</tbody>
</table>

*Notes: ICT = Information and Communication Technology; ACTION = A Community Network for Older Adults; ACTIVE = A Community Network for Older Adults in Europe; AGES = A Generation Bridge for Seniors*
<table>
<thead>
<tr>
<th>Program, country</th>
<th>Participants</th>
<th>Program detail</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (years)</td>
<td>Older adults, n</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lonely or socially isolated</td>
</tr>
<tr>
<td>AO [73], Australia</td>
<td>58-81</td>
<td>7</td>
</tr>
<tr>
<td>Collage and storytelling [71], Australia</td>
<td>Not specified</td>
<td>3</td>
</tr>
<tr>
<td>Demiris et al [58], United States</td>
<td>&gt;65</td>
<td>4</td>
</tr>
<tr>
<td>Digital age [59], Northern Ireland</td>
<td>Not specified</td>
<td>82</td>
</tr>
<tr>
<td>Program, country</td>
<td>Participants</td>
<td>Program detail</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Age (years)</td>
<td>Older adults, n</td>
</tr>
<tr>
<td>Esc@pe [75], Netherlands</td>
<td>Mean 66</td>
<td>12</td>
</tr>
<tr>
<td>InTouch [61], Canada</td>
<td>Mean 92.2 (SD 3.0)</td>
<td>11</td>
</tr>
<tr>
<td>LINE [54], Taiwan</td>
<td>Mean 81.1 (SD 8.5)</td>
<td>32</td>
</tr>
<tr>
<td>Loi et al [57], Australia</td>
<td>Mean 69.9</td>
<td>5</td>
</tr>
<tr>
<td>Program, country</td>
<td>Participants</td>
<td>Program detail</td>
</tr>
<tr>
<td>------------------</td>
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<td>----------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age (years)</td>
</tr>
<tr>
<td>Media Parcels [64], United Kingdom</td>
<td>82</td>
<td>1</td>
</tr>
<tr>
<td>Media Parcels [55], Taiwan</td>
<td>Mean 74.4 (SD 10.2)</td>
<td>24</td>
</tr>
<tr>
<td>Neves et al [56], Canada</td>
<td>74-95</td>
<td>12</td>
</tr>
<tr>
<td>Plymouth SeniorNet [65], United Kingdom</td>
<td>One-to-one help: mean 79.0 (SD 7.5); group help: mean 74.3 (SD 8.2)</td>
<td>144</td>
</tr>
<tr>
<td>Program, country</td>
<td>Participants</td>
<td>Program detail</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------</td>
<td>----------------</td>
</tr>
<tr>
<td><strong>PRISM [66], United States</strong></td>
<td>Age (years): Mean 76.9 (SD 7.3), Older adults, n: 300</td>
<td>Lonely or socially isolated: Not specified, Settings: Community-dwelling, Duration: 12 months, Strategy: PRISM software app included internet access, an annotated resource guide, a dynamic classroom feature, a calendar, a photo feature, email, games, and web-based help.</td>
</tr>
<tr>
<td><strong>Skype [53], United States</strong></td>
<td>Age: 71-97, Older adults, n: 40</td>
<td>Lonely or socially isolated: Not specified, Settings: Long-term residential care (nursing home), Duration: 14 weeks, Strategy: The Skype video-conferencing intervention took place on a weekly for a total of 10 sessions over a 14-week period in a private room at the nursing home.</td>
</tr>
<tr>
<td><strong>Skype on Wheel [60], United States</strong></td>
<td>Age: Not specified, Older adults, n: 20</td>
<td>Lonely or socially isolated: Not specified, Settings: Long-term residential care (care home), Duration: 6 weeks, Strategy: Students from local school and older adults across 3 care homes in engaged in Skype video calls over a 6-week study. Residents were supported by care staff; students accessed Skype from school laptops. A conversational aid was trialed with students to assist their conversation with an older generation.</td>
</tr>
<tr>
<td><strong>StoryBox [70], country not specified</strong></td>
<td>Age: 63-76, Older adults, n: 8</td>
<td>Lonely or socially isolated: Not specified, Settings: Community-dwelling, Duration: 2-4 weeks, Strategy: StoryBox alleviates the barriers of communication between different generations. For young grandchildren, this often means the sharing of crafts, drawings, stickers, and short exclamations. For grandparents, the device provides a way to digitize analog memories and use handwriting for communication.</td>
</tr>
</tbody>
</table>

**Intergenerational component**: Digital interaction with family
**Device**: Computer
**Training for older adult**: Yes
<table>
<thead>
<tr>
<th>Program, country</th>
<th>Participants</th>
<th>Program detail</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td><strong>Lonely or socially isolated</strong></td>
<td><strong>Settings</strong></td>
</tr>
<tr>
<td>Tech Allies [77], United States</td>
<td>Mean 75 (SD 7.9)</td>
<td>Yes</td>
</tr>
<tr>
<td>Tele-BA [74], United States</td>
<td>Mean 74.4 (SD 8.2)</td>
<td>Yes</td>
</tr>
<tr>
<td>Telesenior [67], Belgium</td>
<td>Mean 72 (SD 9.3)</td>
<td>Not specified</td>
</tr>
<tr>
<td>Tlatoque [68], Mexico</td>
<td>Not specified</td>
<td>2</td>
</tr>
<tr>
<td>White et al [76], United States</td>
<td>Mean 71 (SD 12)</td>
<td>Not specified</td>
</tr>
<tr>
<td>Program, country</td>
<td>Participants</td>
<td>Program detail</td>
</tr>
<tr>
<td>------------------</td>
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<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Age (years)</td>
<td>Older adults, n</td>
</tr>
<tr>
<td>Williams et al [72], United States</td>
<td>Phase 1: 59-86; phase 2 54-82</td>
<td>Phase 1: 16; phase 2: 29</td>
</tr>
<tr>
<td>You, me and television [69], Portugal</td>
<td>65-73</td>
<td>3</td>
</tr>
</tbody>
</table>

aICT: information and communications technology.
bMSN: Microsoft Network.

**Level of Contribution and Methodological Quality**

An overview of the level of contribution and methodological quality of the documents elaborating the 27 programs is presented in Table 2. On the basis of the level of contribution assessment, 20 programs were rated as having a high level of contribution to the context, mechanism, and outcome. Across the programs, descriptions of mechanisms and outcomes were less developed than descriptions of contexts. All studies met at least 2 of the 5 MMAT criteria. The detailed MMAT appraisal of documents evaluating the digital intergenerational program is shown in Multimedia Appendix 3.
<table>
<thead>
<tr>
<th>Program</th>
<th>Quality appraisal</th>
<th>Associated MMAT (^a) scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Context</td>
<td>Mechanism(^b)</td>
</tr>
<tr>
<td>ACTION</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>ACTION (redesigned)</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>ACTIVE</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>AGES 2.0</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>AO</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Collage and storytelling</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Demiris et al</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Digital age</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Esc@pe</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>InTouch</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>LINE</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Loi et al</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Media parcels</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>MSN(^c) or Skype</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Neves et al</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Skype</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Skype on Wheel</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>StoryBox</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Tech Allies</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Tele-BA</td>
<td>High</td>
<td>High</td>
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<tr>
<td>Telesenior</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Tlatoque</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>PRISM</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>White et al</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Williams et al</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Plymouth SeniorNet</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>You, me and television</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

\(^a\)MMAT: Mixed Methods Appraisal Tool.
\(^b\)Consists of strategy and mechanism.
\(^c\)MSN: Microsoft Network.

**S-C-M-O Configurations**

Of the candidate S-C-M-O configurations based on the authors’ description (Multimedia Appendix 4), 4 S-C-M-O configurations were substantively supported by the available evidence (Figures 3-6). We present the configurations with key examples of strategies, contexts, mechanisms, and outcomes from the reviewed documents. S-C-M-O configurations 1 and 2 focused on community-dwelling older adults, S-C-M-O configuration 3 focused on older adults residing in long-term residential care facilities, and S-C-M-O configuration 4 focused on older adults who are lonely.
**Figure 3.** Strategy-Context-Mechanism-Outcome configuration 1 involving provision of access and training to digital technology for community-dwelling older adults.

**Figure 4.** Strategy-Context-Mechanism-Outcome configuration 2 involving provision of digital psychosocial support and education by nurses for community-dwelling older adults.

**Figure 5.** Strategy-Context-Mechanism-Outcome configuration 3 involving video call with older adults in long-term residential care facilities.

**Figure 6.** Strategy-Context-Mechanism-Outcome configuration 4 involving videoconference behavioral activation for older adults who are lonely.

### S-C-M-O Configuration 1

A total of 4 programs contributed to this S-C-M-O configuration: ACTION [62], Plymouth SeniorNet [65], PRISM [66], and Tlatoque [68]. For community-dwelling older adults, provision of access to and training in digital technology may increase their self-efficacy in digital devices, thereby increasing the use of digital-based communication with family (Figure 3). The outcomes observed for the 4 programs included reduced loneliness [65,66], reduced social isolation [66], and increased frequency of contact [62,68].

In all 4 programs, the devices were provided free of charge for older adults. Of the 4 programs, 2 (PRISM [66] and Tlatoque [68]) used apps or systems specially designed for older adults, which may have “eased the adoption of the technology” [68]. The other programs used commercially available digital communication modes, for example, email (n=2) [62,65] and Skype (n=1) [65].
The mode of training included one-to-one, group, and a combination of one-to-one and group training. In the Plymouth SeniorNet program, older adults attending group sessions appeared to have a greater reduction in loneliness as compared with those in one-to-one sessions, although the results from the two modes of training may not be comparable, as the allocation was not random [65]. Participants in the Plymouth SeniorNet program also mentioned that training conducted by someone closer to their age was important [65].

**S-C-M-O Configuration 2**

One program (Telesenior [67]) contributed to the S-C-M-O configuration. For community-dwelling older adults, digital psychosocial support and educational interventions from nurses were useful in reducing loneliness (Figure 4). In the Telesenior program, digital psychosocial support and educational interventions were delivered through video-telephone to homebound older adults based on 3 principles: contact and communication, safety and protection, and care mediation [67]. The digital psychosocial support and educational interventions from nurses can provide “a network of relationships which the older adults felt accepted, had common interests and concerns, and found help, advice, and support” [67]. In the Telesenior program, older adults who were older (>66 years old), were widowed, lived alone, had financial problems, and used several health and social services showed improvement in feelings of social loneliness after participating in the program [67].

**S-C-M-O Configuration 3**

A total of 7 programs—ACTIVE [52], Demiris et al [58], Digital Age [59], LINE [54], Microsoft Network (MSN) or Skype [55], Skype [53], and Skype on Wheel [60]—contributed to this S-C-M-O configuration. In this review, we found that video calls with students or families may be useful in reducing loneliness among older adults residing in long-term residential care facilities (Figure 5). Only 1 program (Skype on Wheel [60]) evaluated intergenerational communication with students from a local school, whereas the other 6 programs (LINE [54], MSN or Skype [55], Skype [53], ACTIVE [52], Demiris et al [58], and Digital Age [59]) were designed to facilitate communication with family members or friends of older adults in long-term residential care facilities. It has been hypothesized that a video call helps in language interaction as well as verbal and nonverbal elements of communication. Video calls may also aid in promoting a social presence for older adults and family members [58]. The outcomes observed for the 7 programs included reduced loneliness [53,54,58,79], reduced social isolation [58], and improved social participation [52,59,60].

A total of 4 programs used existing software programs, including LINE [54], MSN [55], and Skype [52,53,55] for video calls, whereas 1 program used videophones [58]. For programs using commercially available software, smartphone [54], tablet [52,60] and laptop [55] have been used. The frequency of contact between older adults and their families was designed to be once per week in 4 programs—LINE [54], MSN or Skype [55], Skype [53], and Demiris et al [58].

As highlighted in the Skype on Wheel [60] program, “younger generations (grandchildren) may not be sure of how to communicate with their elderly relatives”; therefore, it may be helpful to provide conversational aid to facilitate intergenerational communication, such as a list of possible conversational topics as seen in 2 programs (Skype on Wheel [60] and LINE [54]). Although not developed for older adults residing in long-term residential care facilities, other programs have investigated digital storytelling [70] and exposure to photographs in the older adults’ environment [68] as ways to facilitate intergenerational conversation.

A total of 2 programs (ACTIVE [52] and Digital Age [59]) explicitly included training on using digital technology for older adults residing in long-term residential care facilities. In the ACTIVE program, the authors highlighted that “a carefully selected, smaller set of basic apps was installed when the intervention started” to avoid overwhelming the older adults [52]. The content of the training is well described in the Digital Age program [59], which includes the following core subjects: learning how to use a tablet, browsing the internet, staying safe on the internet, emailing, using an App Store, and video calling. The content of the training sessions was flexible and tailored to the needs of older adults in the Digital Age program [59].

**S-C-M-O Configuration 4**

One program, Tele-Behavioral Activation (BA) [74], contributed to this S-C-M-O configuration. We found that behavioral activation provided through videoconferencing by a lay coach may be useful in reducing loneliness among older adults who are lonely (Figure 6). Several studies have evaluated the effectiveness of digital training courses [72,73,75,77] in reducing loneliness or social isolation for older adults who were lonely or socially isolated. However, as highlighted in the Assertive Outreach (AO) program, establishing “even a small web-based social network proved very difficult in many cases” for older adults who were socially isolated, which may have resulted in the lack of improvement in the outcomes in most of these studies [73]. BA is a brief, structured behavioral approach that aims to increase and reinforce wellness-promoting behaviors that can be conducted by lay coaches [74]. In the Tele-BA program, lay coach “worked with participants to identify and schedule value-based activities, rewarding social engagement and activities, and using strategies to reduce and solve barriers to social connectedness [74]. Participants first reviewed their daily activity patterns, then chose activity goals, worked on specific implementation plans, and reviewed their successes and areas for improvement” [74]. This may have enabled older adults to learn to overcome barriers to social connectedness and to use skills for maintaining social connectedness over time, leading to reduced levels of loneliness that were sustained beyond the 5 sessions of tele-BA.

**Discussion**

**Principal Findings**

In this review, we sought to answer the following question: “How do different digital intergenerational programs interact with different contexts to produce certain outcomes?” This review revealed that different strategies should be adopted for different groups of older adults (eg, older adults who are lonely, older adults who reside in long-term residential care facilities, or older adults who reside in long-term residential care facilities).
and community-dwelling older adults). For example, providing training and access to digital technology may be useful in reducing loneliness among community-dwelling older adults but not for older adults who are already lonely or socially isolated. This may be because establishing “even a small web-based social network proved very difficult in many cases” for older adults who are socially isolated as discussed in the AO program [73]. Similar to AO, Tech Allies program also pointed out the older adults “were already facing many contextual factors in their daily lives, such as physical disability and a lack of close friends and living relatives” would make “their loneliness more systemic and harder to change” [77]. Although tele-BA by lay coaches may be helpful for lonely older adults, future studies should explore different program strategies for this subgroup of older adults with more complex needs. A possibility is to entail young volunteers to befriend older adults who lack existing social support [81]. Williams [72] investigated the effect of a 2-week computer-mediated communication course for lonely older adults and found “no significant difference in loneliness between pre-test and post-test” [72]. However, as explained by the author, the lack of observed differences after the intervention was not unexpected with the short duration of the intervention (2 weeks) [72]. Therefore, the duration of intergenerational programs should be considered before implementation.

Among the digital intergenerational programs included in this realist review, 2 programs (AGES 2.0 [48] and White et al [76]) targeted both community-dwelling older adults and older adults residing in long-term care facilities by providing training in digital technology. However, both the programs demonstrated unsuccessful outcomes [48,76]. A possible reason for the unsuccessful outcome from these 2 programs may be that although providing training in digital technology may be useful to reduce loneliness among community-dwelling older adults based on S-C-M-O configuration 1 (all 4 programs in S-C-M-O configuration 1 achieved successful outcomes), this program strategy may not be useful for older adults in long-term residential care facilities. This further supports the importance of designing targeted digital intergenerational programs for different groups of older people (eg, older adults residing in long-term residential care facilities and community-dwelling older adults). The AGES 2.0 study also found that “feelings of self-competence, social engagement, and maintenance of identity were critical to the intervention’s success” [48]. Future research should explore whether interventions that enhance these aspects are useful in promoting social connectedness among older adults.

Comparison With Prior Work

In a previous realistic review exploring the use of technology to engage hospitalized patients, the authors found that a user-centered design may increase the engagement level [82]. However, in our realistic review of digital intergenerational programs based on digital technology, only 3 programs designed for community-dwelling older adults incorporated a user-centered design [63,66,69], and 2 programs were evaluated in a small sample (n<10) [63,69]. Studies in long-term residential care facilities using existing digital communication tools such as LINE and Skype demonstrated beneficial effects on reducing loneliness [54,55], which implies that user-centered design may not be critical for the success of digital intergenerational design. However, this could be because staff are available at long-term residential care facilities to assist with the set-up of the video call tools in these programs, which facilitates intergenerational communication with family members or students [54,55,60] and mitigates the potential problem of digital illiteracy among older adults [83,84]. Future research should be conducted to examine whether a user-centered design may have contributed to a reduction in loneliness or social isolation among specific groups of older adults.

Strengths and Limitations

This review is the first to use a realist framework to study digital intergenerational programs for older adults. The realist framework allowed us to consider empirical findings and theories together to understand how these programs worked. Previous reviews on the effectiveness of intergenerational programs have focused primarily on scholarly literature [29-31] and, therefore, have provided limited insight into the complex causal pathways that may underpin the efficacy or effectiveness of intergenerational programs. The inclusion of diverse research designs, such as quantitative, qualitative, and mixed methods studies, enabled this review to leverage the strengths of each approach. From a realistic perspective, this diversity has huge explanatory value and can help uncover contexts and mechanisms not typically captured in traditional systematic reviews and meta-analyses [33].

However, a limitation of this realist review is that nearly half (11/27, 41%) of the programs reported only quantitative results. A problem with conducting a realist review of quantitative studies is that their primary emphasis is on quantitative results; thus, there may be fewer descriptions and explanations of the mechanisms [85]. Thus, our realist review generally focuses on screening the discussion section of publications to identify author opinions or any qualitative information that may provide information on the mechanisms of how certain programs work. As we inferred most of the information regarding the mechanism from the authors’ comments and discussions in the quantitative studies, we acknowledge the subjectivity of these inferences. Nevertheless, the S-C-M-O configurations derived from this study may serve as a basis for further studies to corroborate the proposed theory and mechanisms that drive program outcomes in different contexts.

Second, we acknowledge that for some programs, the outcome observed may not be solely attributable to intergenerational interaction, as the participants may interact with their peers or spouses using digital technology. We decided to include these studies, as there was only 1 study [70] focusing solely on intergenerational interaction using digital technology. However, the inclusion of programs that accommodate both nonintergenerational and intergenerational communication provides a more comprehensive list of programs available for intergenerational communication. As such, some programs in this review may need to be adapted for intergenerational interactions only, and their effectiveness in addressing isolation and loneliness may require investigation in future studies.
Third, as the search in the scholarly literature was restricted to articles published before August 2020, our review may have excluded studies published after the cutoff date. Nevertheless, the findings of this review can serve as a foundation for future research on digital intergenerational programs.

Finally, another limitation of this study was the inclusion of only English-language documents, which may have potentially led to the omission of relevant programs from English-speaking countries. Among the 27 programs included in this review, only 2 (7%) programs were conducted in Asian countries [54,79]. However, the inclusion of only English-language documents minimizes potential information loss during translation.

**Conclusions**

This review identifies the key strategy, context, and mechanism that influence the success of programs in reducing loneliness or isolation among older adults by potentially promoting intergenerational interaction through digital means. Digital interventions are becoming increasingly popular to tackle social problems, such as loneliness and social isolation. We identified 4 S-C-M-O configurations to consider when developing intergenerational programs for older adults. Future studies, especially quantitative studies, should consider clearly describing the components of the program and their corresponding contexts and mechanisms driving the improvement of outcomes in digital intergenerational programs. With a better understanding of the components and mechanisms of digital intergenerational programs, well-informed decisions can be made when planning or developing digital intergenerational programs.

**Acknowledgments**

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**Data Availability**

The data sets generated during and/or analyzed during this study are available from the corresponding author upon reasonable request.

**Conflicts of Interest**

None declared.

**Multimedia Appendix 1**

Search strategies in databases.

[DOCX File, 15 KB - aging_v6i1e39848_app1.docx ]

**Multimedia Appendix 2**

List of studies excluded during full text screening.

[DOCX File, 29 KB - aging_v6i1e39848_app2.docx ]

**Multimedia Appendix 3**

Mixed Methods Appraisal Tool appraisal for documents evaluating digital intergenerational program.

[DOCX File, 19 KB - aging_v6i1e39848_app3.docx ]

**Multimedia Appendix 4**

Candidate Strategy-Context-Mechanism-Outcome configurations for digital intergenerational programs based on the authors’ description.

[DOCX File, 27 KB - aging_v6i1e39848_app4.docx ]

**References**


79. Tsai HH, Tsai YF. Changes in depressive symptoms, social support, and loneliness over 1 year after a minimum 3-month videoconference program for older nursing home residents. J Med Internet Res 2011 Nov 15;13(4):e93 [FREE Full text] [doi: 10.2196/jmir.1678] [Medline: 22086660]


**Abbreviations**

AO: Assertive Outreach  
BA: Behavioral Activation  
MMAT: Mixed Methods Appraisal Tool  
MSN: Microsoft Network  
S-C-M-O: Strategy-Context-Mechanism-Outcome
Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR Aging, is properly cited. The complete bibliographic information, a link to the original publication on https://aging.jmir.org, as well as this copyright and license information must be included.
Abstract

Background: Digital technologies were implemented to address the disruption of long-term care facility residents’ socialization needs during the COVID-19 pandemic. A literature review regarding this topic is needed to inform public policy, facility managers, family caregivers, and nurses and allied health professionals involved in mediating the use of digital devices for residents’ social ties.

Objective: Our study outlines key concepts, methodologies, results, issues, and gaps in articles published during pandemic-related visitation restrictions.

Methods: Following the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) protocol, a scoping review was conducted by searching 3 database aggregator platforms (EBSCO, ProQuest, and PubMed) for studies published in peer-reviewed journals from early 2020 to the end of June 2021, when the most stringent restrictions were in place. We included qualitative and quantitative studies, reviews, commentaries, viewpoints, and letters to the editors in French or English focusing on digital technologies aiming to support the social contact of residents in long-term care facilities during pandemic-related visitation restrictions.

Results: Among 763 screened articles, 29 met our selection criteria. For each study, we characterized the (1) authors, title, and date of the publication; (2) country of the first author; (3) research fields; (4) article type; and (5) type of technology mentioned. The analysis distinguished 3 main themes emerging from the literature: (1) impact and expectations of remote social contact on the physical and mental health and well-being of the residents (n=12), (2) with whom or what the social contact took place (n=17), and (3) limitations and barriers to significant social contact related to digital technologies (n=14). The results first underlined the highly positive impact expected by the authors of the digital technologies on health and quality of life of residents of long-term care facilities. Second, they highlighted the plurality of ties to consider, since social contact takes place not only with family
caregivers to maintain contact but also for other purposes (end-of-life videoconferences) and with other types of contact (eg, with staff and robots). Third, they exposed the limitations and barriers to significant contact using digital technologies and outlined the required conditions to enable them.

**Conclusions:** The review demonstrated the opportunities and risks outlined by the literature about the implementation of digital technologies to support remote social contact. It showed the plurality of ties to consider and revealed the need to evaluate the positive impact of remote contact from the residents’ perspectives. Therefore, to go beyond the risk of digital solutionism, there is a need for studies considering the holistic impact on health regarding the implementation of digital technologies, including the meaning residents give to interpersonal exchanges and the organizational constraints.

**Trial Registration:** OSF Registries osf.io/yhp3x; https://osf.io/yhp3x

**KEYWORDS**

social isolation; COVID-19 pandemic; remote care; nursing homes; social ties; digital devices; older adults

**Introduction**

**Background**

One of the most significant issues of the COVID-19 pandemic has been the effects on long-term care facility residents, who represent 50% of deaths in Europe [1]. Beyond the increase in mortality directly caused by COVID-19, the social distancing measures accelerated declines in mental and physical health among some long-term care facility residents [2], as strict social isolation can cause psychological distress [3]; worsen depression, anxiety, and dementia; and contribute to failure to thrive [4]. In addition, there is some collateral damage caused by delayed surgery and dental care, which has been associated with depression issues [5].

Information and communication technology use has been considered a means to maintain older adults’ quality of life and provide them with solutions to fight the onset of depression, while also limiting face-to-face contact to protect them from the risks of viral transmission [6]. Beyond the impact on health and quality of life, this study considered the socialization needs of residents as important, considering socialization as a basic human need [7]. People in vulnerable situations require particular attention, especially when their ability to communicate their needs is altered, making such expression often difficult to comprehend. Therefore, we were particularly interested in the way digital devices have been implemented or envisaged meeting these socialization needs during visitation restrictions due to the pandemic.

Previous research has addressed the topic of long-term care facility residents’ remote social contact—social contact being defined as an exchange between 2 (or more) people [8]. Televisits with residents’ families were analyzed from the perspective of enhancing social presence and the organizational constraints. Third, they exposed the limitations and barriers to significant contact using digital technologies and outlined the required conditions to enable them.

Researchers have identified limitations such as inhibited videoconferencing use due to age-related cognitive decline and physical frailty [13] and the acceptability of videoconferencing by residents’ families, which is inversely proportional to the length of a resident’s stay [14]. A major contribution from work on this topic, which has primarily focused on cognitively intact residents, is that those most likely to use videoconferencing, considered the “second best option for visitation” [12], are those whose relatives live far away. During the COVID-19 pandemic, the problem of distance arose in another form, as even family members who lived nearby were not allowed to visit their relatives for a relatively long period. Each country and region implemented different restrictions, ranging from strict isolation in rooms to supervised visits during certain circumstances or with mitigating procedures. These restrictions have evolved over time, moving in some institutions from an initial absolute ban to adjusted visitation procedures as knowledge about the virus has evolved [15].

**Objective**

Thus, this scoping review aimed to report on research articles that emerged during the period when the most stringent restrictions were in place, from March 2020 to June 2021. We focused on how technological devices have been or should be mobilized, according to the authors, to meet long-term care facility residents’ socialization needs. Although other recent scoping or rapid reviews addressing the pandemic context focused on social isolation among older adults [16], strategies and actions to enable residents to maintain meaningful family connections [17], or the impact of the pandemic on older adults [18], to our knowledge, our scoping review is the first to specifically address the socialization needs through digital means during visitation restrictions of long-term care facility residents. We therefore conducted a scoping review to provide an overview of existing research on the links between digital technologies and social isolation in long-term care facilities during the COVID-19 pandemic, guided by the following research question: How are the links between digital technologies and social isolation described in the current scientific literature for older adults living in nursing homes during the COVID-19 pandemic?
Methods

Protocol and Registration
This review was conducted according to the scoping review stages described by Arksey and O’Malley [19] and in the extension by Peters et al [20]. The steps include (1) formulating the research question; (2) identifying relevant studies; (3) selecting relevant studies; (4) charting the data; (5) collating, summarizing, and reporting the results; and (6) consultation. We used PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) [21]. The study was preregistered (see Multimedia Appendix 1 for details).

Eligibility Criteria
Our eligibility criteria were developed within the PICo (Population or Problem, Interest, Context) framework (see Multimedia Appendix 2 for details). We included qualitative and quantitative studies, reviews, commentaries, viewpoints, and letters to the editors in French or English focusing on digital technologies aiming to supporting the social contact of residents in long-term care facilities during visitation restrictions due to the COVID-19 pandemic. A central criterion was that specific concepts are used to account for the social contact of residents (eg, social networks, social support) or lack thereof (eg, social isolation, loneliness). Even if the use of digital technologies in long-term care facilities was not the main topic, at least part of the article should be dedicated to it. We included articles published in peer-reviewed journals when the most stringent restrictions were in place, from March 2020 to June 2021.

We excluded articles in a language other than French and English and those in which we were unable to clearly identify the target population and context (eg, quantitative studies on older adults without specific focus on long-term care facility residents). We also excluded articles that did not focus on the older adult population and those with no clear correlation between technology use and visitation restrictions during the COVID-19 pandemic.

Information Sources (Database Selection) and Search Strategy
Database selection was conducted in collaboration with librarians from the University of Strasbourg, who were specialists in this type of research. Our aim was to cover a broad disciplinary spectrum, combining research in the social sciences, humanities, management studies, economics, and health sciences. Thus, on June 29, 2021, we conducted research on 3 major platforms: EBSCO, ProQuest, and PubMed. Comprehensive searches were performed, combining keywords correlated with the following: (1) older adults, (2) their need for socialization, covered by (3) technological devices in (4) long-term care facilities during (5) the COVID-19 pandemic. First, we brainstormed to select terms related to these 5 themes, for example: (1) “Older people” OR “elderly” OR “aged.” Then, we searched each database to find related terms out of the Thesaurus (EBSCO and ProQuest) or MeSH Terms (PubMed). For an extensive overview of the search terms selected, please refer to Multimedia Appendix 3, and for a full overview of the searches conducted in each database, please refer to Multimedia Appendix 4. We limited the publication years at the beginning of 2020, that is, shortly before the time when stay-at-home orders emerged in most countries worldwide due to the pandemic, and included all articles meeting our criteria up to the day we conducted the search.

Data Charting Process and Analysis
Several precautions were taken to limit selection bias. We separated the selected articles into 2 equal parts. All the titles were screened by CS and CH in the first subsection and by CL and CH in the second subsection. CL was responsible for arbitrating selection conflicts between CS and CH, and CS was responsible for arbitration between CL and CH. In the second stage, we followed a similar approach, this time focusing on the abstracts. All the titles were screened by CL and CH in the first subsection and by CS and CH in the second subsection. We adopted a 4-point scoring system, with a score of 1 being used to denote articles that were off-topic and a score of 4 for those that were fully aligned. To this, we added comments for the other authors. Papers scoring 4 twice, or at least 3 and 4, were immediately selected. Those below this score were excluded from the first round. We excluded works that did not specifically address the older adult population or clearly excluded long-term care facility residents (eg, “community-dwelling older adults” in the title or abstract). We also excluded articles written in a language other than French or English. CS was responsible for arbitrating selection conflicts between CL and CH, and CL was responsible for arbitration between CS and CH.

In the third step, we screened the full text of the retained articles, each of us responsible for one-quarter of the articles. Together, the study authors formalized a standardized data extraction sheet, in which each author recorded the following for the articles relevant to them: authors, scientific discipline, title, year and month of publication, country of origin, keywords, type of article (eg, view, review, qualitative research), purpose, methods, technology type, key findings (text quote), key concepts, variables used, practical implications, and research perspectives. A simplified version of this table is available in Multimedia Appendix 5.

Results

Selection of Sources of Evidence
Once duplicates were removed, we had retrieved 763 articles. These were mainly published by researchers or hospital practitioners with the aim of shedding light on the situation. Only articles from peer-reviewed journals were selected. Excluded articles were those in which resident socialization and use of digital devices were not directly correlated as a primary or secondary theme (in a subsection). However, we chose to include articles on past research if the authors discussed it in relation to the current pandemic context. This led us to select 268 articles that were screened for eligibility. We rejected 232 articles because one or more of our selected themes was missing. Finally, of the 32 articles selected at this stage, 3 more were removed: 2 were quantitative studies in which long-term care facility residents were included in a larger panel of older adults.
without this population being analyzed specifically. Another viewpoint article was removed because long-term care facilities were not directly specified. We thus selected 29 articles for analysis (Figure 1).

**Figure 1.** Flow diagram for the search and selection process.

**Characteristics of Articles Included in the Review**

Multimedia Appendix 5 details the characteristics of the 29 articles: (1) authors, title, and date of publication; (2) country of the first author; (3) research fields; (4) article type; (5) type of technology mentioned.

Among the 29 included articles, 12 were published between March 2020 and July 2020, during the early months of the pandemic; 22 were published in 2020, and 7 were published between January 2021 and June 2021.

Regarding the first authors of the articles, 13 were from North America, 11 were from Europe, 2 were from Australia, 2 were from Asia, and 1 was from the Middle East. Of the articles, 4 were from an international perspective, 6 were multidisciplinary (crossing disciplines from health sciences, human and social sciences, and engineering), 18 were primarily from a health sciences perspective (nursing science, psychiatry, public health, psychogeriatric, geriatrics, medicine), 4 were written mainly by social science researchers (anthropology, social work, psychology), and 1 was written by a “think-and-do tank” director.

Regarding article type, 14 articles were commentaries (n=9), viewpoints (n=4), or a letter to the editor (n=1). There were 7 review articles, including systematic (n=1), narrative (n=2), scoping (n=2), protocol for a scoping (n=1), and rapid (n=1) reviews, and 8 articles were based on either qualitative (n=5) or quantitative (n=3) empirical studies.

We then conducted a qualitative analysis of the papers included to answer our research questions. It appeared heuristic to distinguish the articles according to the following: (1) impact and expectations of remote social contact on the physical and mental health and well-being of the residents (n=12), (2) with whom or what the social contact took place (n=17), and (3) limitations and barriers to significant social contact related to digital technologies (n=14).

**Expectations of Remote Social Contact on Residents’ Health and Well-being**

The first expectation regarding digital technologies used in long-term care facilities during the visitation restrictions related to the COVID-19 pandemic was enablement of residents’ social contact because of its positive effects. To address the positive effects of social contact, the authors used several terms.
articles referred to the residents’ socialization needs through the lack of social contact [7,16,22-24]. Authors used the concept of “social isolation” to describe the absence of face-to-face contact, which can be measured objectively [16]; it usually correlated with the concept of “loneliness," which is the “subjective experience of feeling alone or disconnected from others” [25]. Other authors referred to the residents’ socialization needs through social connection [7,17,23,26-28]. Bethell et al [7] defined “social connection” through the combination of the following interrelated concepts: social networks (webs of social relationships), social support (emotional, social, physical, and financial help), social engagement (taking part in activities), and social connectedness (feelings of being cared for and belonging). Social integration was related to the belonging to a social network [29].

Most authors cited in this subsection assumed that technology use would necessarily have a positive effect. The use of technologies to communicate (eg, video calls via phones and tablets) was reported to promote social connection [7] and allow residents with dementia to engage well with others [24]. The impact of technology use on quality of life by facilitating communication with family members or for video consultations was also noted [22]. Social isolation could be alleviated by connecting with the outside world, gaining social support, boosting self-confidence, and engaging in activities of interest [30]. Social connections through technology were linked to enhanced well-being, protecting and improving mental health, and maintaining physical health and independence among older adults [18]. Office et al [31] noted the positive impact of a telephone befriending program on older adults’ perceived health and well-being. Providing technology-dependent amenities to long-term care facility residents could also increase their self-perceived health [32]. In their narrative review, Gorentko et al [25] cited a study demonstrating that video calls set up by staff could have positive effects on depression and loneliness. However, some work did not address so much the positive effects of social contact at a distance but rather the prevention of the negative effects of social distance. Thus, the integration of digital connectivity could help overcome social isolation and loneliness [26] or at least reduce their prevalence [33]. Social isolation can lead to fear, depression, anxiety [34], cognitive decline, fatigue, and sleep disturbances [23]. This implies less infection resistance, more emergency admissions to the hospital, and extended lengths of stay [31]. Technologies were presented as a “key tool” for reducing social isolation [23] for long-term care facility residents who essentially became prisoners in their 1-bedroom living spaces, with this extreme loneliness potentially inducing anxiety, depression, malnourishment, and worsening dementia [32]. Technological devices have been presented as “a boon for residents feeling isolated” [34] regardless of the type: Videoconferencing has shown the same positive effects on depressive symptoms or loneliness regardless of whether a smartphone or a laptop is used [30]. For example, programs were developed for medical student volunteers to have weekly telephone calls with long-term care facility residents [16,31].

Telephone befriending programs can have bidirectional benefits, as students feel empowered by being able to make a difference in the lives of socially isolated seniors [31]. Thus, the authors of the selected articles not only addressed the effects of remote social contact on residents but also focused on their interlocutors, both human and nonhuman, as in the case of interactions with social robots.

**With Whom (or What) the Social Contact Takes Place**

The selected articles paid particular attention to families, with whom it would be essential to maintain a connection. Information and communication technologies should mainly improve meaningful connections between older people and their families in long-term care facilities during the pandemic [17]. Initiatives have emerged worldwide to provide older adults with a connection to the “real world” and means for communicating with friends and family [26]. Public authorities have also addressed this issue. For example, the Italian Ministry of Health published a circular requiring residential facilities to provide residents with access to their families and friends through technological communication to facilitate social occasions and affective interactions [33].

Many interventions to maintain connections between residents and their families were addressed [27], such as the “Friend in Deed” program [28] or the Rhode Island assisted living facility program, which distributed tablets to residents to video call their families, thus facilitating social engagement [23]. Other “useful social contacts” included other care home residents, increasing their social networks by connecting two or more care homes through video calls over a long period, within the framework of a study [35].

There was a specific issue of concern in 3 articles included in this scoping review: the use of technology to avoid dying alone despite the impossibility of visits [27]. Videoconferencing was useful for family visits or consultations for patients dying from COVID-19 complications [16], providing a last chance for older adults and their relatives to “say goodbye” [17]. Two articles addressed the perspectives of residents’ relatives, showing that online communication provided them with support through their social networks [36] to cope with their loved one’s end of life and death. It is indeed possible to share online resources for bereavement support [28].

In addition to family relationships, care modalities (and, consequently, social contact with professionals) also evolved with technology during the pandemic, although not much discussion was provided on this issue. The topic was addressed by 2 articles, showing, for example, that telehealth solutions for geriatric mental health care [26], such as telephone or video conferences [34], allowed for the delivery of convenient, accessible, and affordable care [26]. Although rarely mentioned in the literature, staff members have also asked to use technological solutions to connect with residents (virtual therapy sessions, telehealth visits, video calls with friends and family, virtual activities in their rooms [16]). Special attention was also paid to families, as some social workers developed telesupport interventions for family caregivers [37].

From another perspective, 4 articles addressed the relationships between humans and technology, showing that direct contact with technological devices can help long-term care facility residents cope with social distancing related to COVID-19.
Social robots can have a positive impact on loneliness by enhancing autonomy, increasing levels of engagement [38], and encouraging attachment and social integration among older adults [29]. For example, Sunshine’s robot’s (a Korean-manufactured, English-speaking doll-chatbot system) conversations (playing songs, cueing reminiscences, quoting inspirational passages, telling stories, playing “Simon Says”) could encourage exercise and social engagement and calm agitation; may have positive effects on geriatric depression, sleep quality, and cognition; and can encourage previously unresponsive residents to express themselves [39]. Further, direct social robots are considered a means to empower older adults with few social resources: Playing a mediating role in the care of older adults, they contribute to creating social connectivity [29]. Augmented reality was also noted as a way to reduce the burden of frailty and increase well-being and social participation [32].

However, the impact of direct social robots (eg, animal robots with various sensors that can react to stimuli or software humanoid agents that assess older adults’ affective states and engage in daily conversations with the aim of reducing social isolation) is nuanced [40]. They mainly provide emotional support, whereas online social platforms, for example, provide easy access to information sources and opportunities to communicate. Online social platforms are multifaceted systems that are expected to promote social participation, cognition, physical activity, nutrition, and sleep.

Authors do not always take for granted that technological solutions are easy to implement and correspond to residents’ needs. Some articles selected for this systematic scoping review also pointed out obstacles and limitations, which we address in the following subsection.

Limitations and Barriers to Significant Social Contact Related to Digital Technologies

This review showed that neither the use of technology nor the establishment of real social ties is automatic. Implementing video communications requires an adequate organizational structure and consideration of the ability of the residents’ family members to use the technology [41]. Some authors have considered the digital exclusion of residents’ families [28,33] as well as infrastructural and staffing constraints in long-term care facilities [7,25,42-44]. Moyle et al [13] outlined the time needed to mediate videoconferencing and the difficulty of adding it to the team’s workload, which requires the long-term care facility teams to reorganize their functioning.

Among the 29 articles, 14 highlighted the barriers of using technology to meet long-term care facility residents’ social needs. This subsection discusses the limits of technology used to reduce isolation in general; however, the authors of the reviewed articles mainly focused on the digital divide and (the limits of) technological devices. Only Vernooij-Dassen et al [45] stated that “older adults need more than virtual contacts.”

The digital divide was approached in the reviewed studies from several angles. First, older adults often need assistance using digital technologies, and the most vulnerable have no access to web resources or the required digital skills [18]. Older age, combined with lower income and less education, can lead to reduced access to technology [26], inducing a notably negative impact on access to mental health care [46]. According to Eghesadi [32], exclusion from technological advances may be due to negative representations of older adults (eg, passivity and lack of capacity to learn), combined with the fact that this population often cannot self-advocate. The digital divide concerns not only older adults but also their families [28], insofar as social disparities restrict technology access [33].

Some authors posited correlations between digital socialization and quality of life but noted that this will not systematically be efficient for residents with low digital literacy [22], especially those with cognitive impairments [22,26]. Fears regarding the security of personal data, difficulties in accessing dedicated tools, and visual or hearing impairments were also identified as barriers [16], which add to the fact that long-term care facility residents do not necessarily understand the interest of digital tools, as in the case of telehealth visits [47]. Several infrastructural issues and limitations have been highlighted, such as staff members’ availability to set up video calls, their access to these types of devices, their capacity to schedule and facilitate these interactions [42], and staff commitment and turnover [25]. Access to technology in long-term care facilities does not necessarily dictate its optimal use [43]. To have a real impact on social isolation and loneliness, professionals need to assist older adults use digital tools [44].

Several considerations should be taken into account: the purchase of dedicated equipment and infrastructure (eg, wireless networks), the allocation of dedicated professional time to accompany each resident, and the issue of human resource capacities (eg, staff training, volunteer recruitment [7].

Discussion

Principal Findings

Overall, this scoping review gives a comprehensive overview of the current literature and shows how the scientific papers published during the period of restricted visits due to the COVID-19 pandemic considered the contribution of digital technologies to residents’ social contact. We can summarize our main findings in 3 points. First, we outlined the main expectations for digital technologies to prevent social isolation and loneliness and defined the terms used. The positive impacts expected of remote connections are detailed as well as the negative effects prevented by the use of digital technologies. Second, while prepandemic work on the topic, as described in the Introduction section, mainly focused on the tie between residents and their families, our study shows that articles published during the COVID-19–related confinement and visitors’ restrictions focused on a plurality of ties. Indeed, social contact took place not only with family caregivers to maintain contact with the residents but also for other purposes (end-of-life videoconferences) and with other types of contact: Several articles addressed remote ties with professional caregivers, student volunteers, and residents of other institutions and even direct contact with social robots. Digital socialization thus concerns intrafamily ties and a broader network of ties. Third, we reported on the limitations and barriers to significant contact.
using digital technologies (digital divide and access difficulties, notably due to cognitive impairment and the low digital literacy of residents and their relatives) and outlined the required conditions to enable them, in particular organizational settings (technological infrastructure, dedicated professional time, human resource capacities).

**Comparison With Prior and Recent Work**

In the literature, the expectations for digital technologies to ensure significant remote connections are high. Digital solutions are generally seen as a natural alternative to face-to-face contact (one exception is Vernooy-Dassen et al [45]). They are considered as suitable methods to care for chronically ill, frail, or dependent older adults while also reducing health care costs [48]. These devices could allow residents to have a new, interesting device to show to visitors, making them an object of social mediation [49] and contributing to the creation of social connectivity [28]. To avoid a tendency for technological solutionism [50], considering that the implementation and appropriation of technologies are synonyms, it seems essential to finely define the implications and entanglements and identify the contributions and limitations of digital solutions used to maintain or develop social ties. This aim can be achieved through an increased number of studies based on empirical methods [51]. Indeed, previous studies on long-term care facility residents’ remote social ties have used standardized scales, such as the Geriatric Depression Scale [10], combined with loneliness and social support behavior scales [11] or with loneliness and quality of life scales [30]. In the corpus studied in our review, some empirical articles evaluating the impact of remote social contact through the lens of health and quality of life issues were conducted before the COVID-19 crisis [29,30,38]. However, the pandemic context itself can be anxiety-provoking [52] and thus influence evaluations related to residents’ health, solitude, and quality of life. Studies conducted during the crises and questioning the significance of the connections are thus required. Moreover, expectations cannot be addressed in a uniform manner, as if residents all have the same identity and history. Multiple dimensions of social identity, such as gender, age, or migration status [53], need to be considered in the studies because they impact the use of digital technologies and meaning of social contact. Conversely, it is necessary to consider the barriers to remote social contact and virtual care, which increased following the pandemic, due to old age [54,55] combined with other characteristics like ethnicity [56].

Regarding the plurality of ties through remote social contact stated in our review, we found that most of the previous studies focused on the relationships between residents and their families [41]. Above all, our results show that extrafamilial ties need to be considered, not only because family involvement after long-term care facility admission can quantitatively decrease [14] but also because other ties are important. Indeed, some residents have remote contact with residents from other long-term care facilities [35], some professionals request digital contact with long-term care facility residents [16], and some meaningful exchanges occur via telehealth solutions [26,34]. Since the related practices are based on affects and moral feelings [57,58] for both caregivers and care receivers [59], we could consider all their social ties: the “family structure, the state and nature of their social relationships both inside and outside the nursing home, and their social practices” [60].

Concerning the barriers and enabling settings for significant remote social contact in long-term care facilities, consideration of organizational issues is novel in the COVID-19-related studies. Although past work did not focus on this subject [41], the organizational perspective of remote social contact mediation is addressed in various articles, particularly in terms of staffing constraints. The literature shows that, since an increase in social service and activity staff has a positive impact on residents’ quality of life [61], long-term care facilities could train their staff to mediate and implement remote social contact. This could be a way to better respond to crises, prepare for the future needs of the residents, and limit the turnover of professionals, as stated in previous work [62].

This review enables us to consider the opportunities for residents’ literacy (highlighted as a barrier to significant remote social contact) by collecting and taking into account their requests for remote connection. The articles reviewed for this scoping review report on neither the residents’ needs for digital contact nor their lived experiences, even in the articles that referred to direct interventions [27,28,31]. Indeed, qualitative studies developed during the pandemic assessed the impact of volunteer phone calls on social isolation [31] or the effect of remote Quizz sessions between residents of several long-term care facilities [35] or stated the usefulness of the technologies used in the research [42]. Quantitative studies measured the number of long-term care facilities reporting the use of digital devices [23] or residents’ preferences between phone and video calls [63]. None of the studies considered the perspective of the residents, as previous research has stated. The need for well-developed and tested interventions was indeed highlighted by Palmdorf et al [51], who showed that there is a lack of information about the actual needs of the users of digital technologies.

**Limitations**

Several limitations concerning our review need to be highlighted. First, the systematic search approach may have been biased, particularly because we were limited by the subscriptions to which our affiliated university provided us access. We cannot exclude the possibility that we overlooked some work published during the examined time period that was related to our research questions. In the future, this bias could be avoided by soliciting co-authors from other universities. Second, our inclusion criterion that only articles from peer-reviewed journals should be included potentially led us to not identify certain work, such as from the grey literature. A less restrictive scoping review, including this grey literature, could be conducted on the same basis. The third limitation is specifically related to our research topic and the period covered. It is very difficult to conduct research during large-scale crises, especially in long-term care facilities that have been particularly affected. Therefore, the empirical material collected by the authors of the reviewed articles is hardly representative or may even be nonexistent in most of the selected articles. A new scoping review using our approach could be conducted covering...
a longer period, assuming that some work may have appeared later.

**Future Directions**

To capture the demand and need of the residents, more in-depth evaluations should be methodologically conducted. Social support, social network, social engagement, and social connectedness should be distinguished in the measurements. These approaches should be complemented by qualitative methodologies to outline residents' subjective experiences regarding digital device use and elucidate the individual, interpersonal, and organizational specifics that impact the experience. Further, we should investigate the social support provided by the staff [42].

Future studies should situate their analyses in a temporal context (before, during, and after social distancing and visitor restrictions), as has been done by researchers with older adults living at home [64], and consider the organizational, geographical, and material dimensions in which the interactions take place. Taking into consideration the expectations of the individuals would also state the gap between the imagined future (generally idealized) and the actual appropriation of the devices [65]. Regarding direct contact with social robots, the nature of this type of tie needs could also be further questioned.

Research programs could be implemented on an international scale in the digital health field, considering the pandemic context, to provide solutions for maintaining and improving the living conditions of older adults in a broad sense, including those living in long-term care facilities [66].

Future studies should analyze if and how remote social contact allows families to stay effective care partners and not solely remote “visitors” during and after COVID-19 epidemic peaks [67]. In other words, it is a matter of evaluating whether these digital devices allow relatives to carry out the family’s care work “at a distance.”

**Conclusions**

This review demonstrated the opportunities and risks outlined by the literature about the implementation of digital technologies to support remote social contact. If the expectations for digital technologies to support significant remote connections are high, the review showed that studies conducted during the crises and questioning the significance of the connections are thus required. This review also showed the plurality of ties to consider and revealed the need to evaluate the positive impact of remote contact from the resident’s perspective. Therefore, to go beyond the risk of digital solutionism, there is a need for studies considering the holistic impact of digital technology implementation on health, including the meaning residents give to interpersonal exchanges and the organizational constraints.

This scoping review opens up perspectives for policy makers in terms of political planning and for long-term care facility managers who have to implement these policies with their staff. Beyond the sole epidemic context, this review’s findings make it possible to identify points of vigilance for implementing digital devices dedicated to socialization among long-term care facility residents, in anticipation of the “digital revolution in health” [68] and care, in the context of demographic aging [69] and increased geographical mobility among new generations [70].

**Acknowledgments**

The scoping review is part of the INNOVEHPAD study (grant number ANR-20-GES1-0004), which was funded by the French National Research Agency (Agence Nationale de la Recherche) and the Region “Grand Est.” We acknowledge support from the librarians from the University of Strasbourg, Aline Demange, Daphné Celet, and Magali Risch, who helped us select databases and platforms suitable for our research. Marion Pecquery was also of great support as a trainee. We would like to thank Editage for English language editing.

**Data Availability**

The data sets generated during or analyzed during the current study are available from the corresponding author on reasonable request.

**Conflicts of Interest**

None declared.
Search terms.

Multimedia Appendix 4
Search equations.

Multimedia Appendix 5
Main characteristics of the selected articles.

References


11. Tsai H, Tsai Y. Changes in depressive symptoms, social support, and loneliness over 1 year after a minimum 3-month videoconference program for older nursing home residents. J Med Internet Res 2011 Nov 15;13(4):e93 P 947 [FREE Full text] [doi: 10.2196/jmir.1678] [Medline: 22086660]

12. Tsai H, Tsai Y. Changes in depressive symptoms, social support, and loneliness over 1 year after a minimum 3-month videoconference program for older nursing home residents. J Med Internet Res 2011 Nov 15;13(4):e93 P 947 [FREE Full text] [doi: 10.2196/jmir.1678] [Medline: 22086660]


64. Kim S. Exploring how older adults use a smart speaker-based voice assistant in their first interactions: qualitative study. JMIR MHealth UHealth 2021 Jan 13;9(1):e20427 [FREE Full text] [doi: 10.2196/20427] [Medline: 33439130]


Abbreviations

**PICo:** Population or Problem, Interest, Context

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Kübra Beliz Budak1,2, BA, MSc; Franziska Laporte Uribe1,2, PhD; Franka Meiland3, PhD; Simone Anna Felding1,2, MSc; Sonja Teupen1,2, PhD; Johannes Michael Bergmann1,2, PhD; Rene Mueller-Widmer1,2, BSc; Martina Roes1,2, DPhil
1Deutsches Zentrum für Neurodegenerative Erkrankungen e.V., site Witten, Witten, Germany
2Department of Nursing Science, Faculty of Health, University of Witten/Herdecke, Witten, Germany
3Department of Medicine for Older People, Amsterdam Public Health Research Institute, Vrije Universiteit Medical Center, Amsterdam, Netherlands

Corresponding Author:
Kübra Beliz Budak, BA, MSc
Deutsches Zentrum für Neurodegenerative Erkrankungen e.V.
site Witten
Stockumer Str. 12
Witten, 58453
Germany
Phone: 49 23 02 926
Email: beliz.budak@dzne.de

Abstract

Background: In the lives of people with dementia, loneliness is an important issue with psychological and physical consequences. Active assisted living (AAL) technology has been gaining visibility in the care of persons living with dementia, including addressing loneliness. However, to the best of our knowledge, there is a lack of evidence concerning the factors influencing the implementation of AAL technology within the context of dementia, loneliness, and long-term care (LTC).

Objective: We aimed to identify the familiarity with AAL technology that is promising for addressing loneliness in persons living with dementia in LTC in Europe and the factors influencing AAL technology implementation.

Methods: A web-based survey was developed based on findings from our previous literature review. The Consolidated Framework for Implementation Research guided the development and analysis of the survey. Participants included 24 representatives of Alzheimer Europe member associations from 15 European countries. The data were analyzed using basic statistical methods (descriptive statistics).

Results: The baby seal robot Paro was reported to be the most familiar AAL technology by 19 of 24 participants addressing loneliness in people with dementia living in LTC. Participants from Norway (n=2) reported familiarity with 14 AAL technologies, and participants from Serbia (n=1) reported zero familiarity. It seems that countries that invest less in LTC facilities are familiar with fewer AAL technologies. At the same time, these countries report a more positive attitude toward AAL technology, express a higher need for it, and see more advantages than disadvantages than those countries that invest more in LTC. However, a country's investment in LTC facilities does not seem to be linked to other implementation aspects such as costs, planning, and the impact of infrastructure.

Conclusions: Implementation of AAL technology to address loneliness in dementia seems to be linked to familiarity with the technology in a country as well as national investment in LTC facilities. This survey confirms the literature on higher investment countries' critical stance in regard to AAL technology implementation to address loneliness in persons living with dementia living in LTC. Further research is needed to clarify the potential reasons why familiarity with more AAL technology does not seem to be directly linked with acceptance, positive attitude, or satisfaction with AAL technology addressing loneliness in persons living with dementia.

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KEYWORDS
loneliness; social isolation; active assisted living technology; long-term care; dementia; Alzheimer; implementation; CFIR

Introduction
Dementia is a growing concern worldwide. The World Health Organization estimates that 10 million people are diagnosed with dementia each year [1]. This growing group of people has specific needs and issues, and one of them is loneliness. Loneliness is defined “as a subjective feeling state of being alone, separated or apart from others and is an imbalance between desired social contacts and actual social contacts” [2,3]. Loneliness among older adults is found to be a factor that may add to the progression of symptoms of dementia and mild cognitive impairment [4]. The predictive power of loneliness on the progression of dementia and MCI is comparable to that of some biological measures, such as higher cortical amyloid burden [5], genetics, diabetes, and vascular diseases [6].

For persons living with dementia, needing to transfer from home to a long-term care (LTC) facility due to disease progression [7] or no longer being able to live safely at home without additional support beyond the care provided by informal caregivers [8] exacerbates the likelihood of loneliness, social isolation, and depression [9]. Loneliness among LTC residents is often addressed by a number of psychosocial interventions, for example, telephone befriending or horticultural therapy [10]. However, the experience of loneliness is largely subjective. As there is no one-size-fits-all approach to addressing loneliness, the need to tailor interventions to suit the needs of individuals is growing [10]. Therefore, adopting technology into the delivery of psychosocial interventions could be seen as an opportunity to address loneliness in the growing group of persons living with dementia. However, it can be a challenge to implement these technologies in LTC settings [11].

Implementation involves a set of planned, intentional activities that aim to put into practice evidence-informed policies and practices in real-world services. The goal of effective implementation is to benefit end users of services—children, youth, adults, families, and communities [12]. Researchers have explored ways to implement technology to aid in the care of persons living with dementia [11]. However, the process of using technology to deliver psychosocial interventions has not often been investigated [13].

In the past 2 decades, there has been an increase in research concerning technology in dementia care [14]. These technological advancements targeted to support persons living with dementia are typically called assistive technology [14]. Assistive technology contains a wide range of technological applications with a potential application to dementia care. These include self-contained devices (eg, tablets, wearables, and personal care robots) and software applications (eg, mobile or web-based apps) [15].

Assistive technology specifically for persons with dementia has been defined as “any item, piece of equipment, product or system driven by electronics, whether acquired commercially, off-the-shelf, modified or customized, that is used to help persons with dementia in dealing with the consequences of dementia” [16]. Assistive technology based on this definition is called active assisted living (AAL) technology [15]. Examples of AAL technology include specialized tablets, wearables, social robots, and integrated smart home systems [15]. AAL technology implementation in real-life practice can still be seen as a challenge [11,16-18], with only a few examples noting some promising insights into the positive impact on loneliness in persons living with dementia [16,18].

A recent review on the implementation factors of social robots in LTC reported a range of barriers, such as complexity, physical accessibility, and cost [17]. The high acquisition and maintenance costs of social robots are one of the primary barriers reported by multiple stakeholders [17]. For example, the average price of a popular robot called Paro is approximately €7000 (a currency exchange rate of 1€=US $1.08) [19], and with funding for LTC facilities ranging from one country to another, those costs can be a barrier [20]. The authors of the review also reported that the beliefs and attitudes of stakeholders present an important barrier to the implementation of AAL technology [17]. The authors noted that there is a scarcity of studies that have explored the perceptions of key stakeholders in LTC, such as care professionals, family, and persons living with dementia, even though it is known that these stakeholders play important roles in the implementation process of technology in LTC [17]. Therefore, an understanding of these stakeholders’ perspectives and experiences is needed to bridge the knowledge gap between research and clinical practice.

To the best of our knowledge, there is a lack of evidence on the range of factors affecting AAL technology implementation in the context of loneliness and dementia. Therefore, this study aimed to identify the influencing factors that hinder or facilitate the implementation of AAL technology for residents with dementia in LTC across Europe and the potential impact of such technology on feelings of loneliness. We focus on countries in Europe for the need to bridge the gaps between dementia care across Europe where different sectors have resulted in a patchwork of approaches to technology without a coherent model while competing with rapid advances in the world [21,22]. Specifically, we were interested in answering the following research questions: (1) How do the European Alzheimer association’s view factors that affect the implementation of AAL technology in LTC facilities to address loneliness in persons living with dementia in their respective regions? (2) What is the perspective of dementia associations on the AAL devices that have been implemented in LTC facilities in their region to address loneliness in persons living with dementia? (3) Are there any other factors regarding AAL technology implementation in LTC that might have potential influence?

Methods
Overview
The paper reports on a web-based survey consisting of a quantitative questionnaire combined with open-ended questions.
Participants were asked fifteen 5-point Likert-scale questions and open-ended questions based on Damschroder “Consolidated Framework for Implementation Research” (CFIR) [21]. The web-based survey tool (LimeSurvey) was used.

Participants

The participants included stakeholders who were experts from European national and regional Alzheimer associations and thus were knowledgeable about the use of AAL technology in their respective country or region. We reached out to Alzheimer associations in 47 European countries, but we were able to contact only 34 Alzheimer associations. All were members of Alzheimer Europe, which is the most comprehensive collaboration of Alzheimer associations in Europe.

We aimed to determine which implementation barriers are experienced in each region and which are perceived to be more relevant to loneliness. Thus, we addressed national and regional Alzheimer associations and inquired whether they were familiar with the general trend of the overall beliefs and attitudes of stakeholders toward the use of AAL technology in LTC facilities. We believe that surveying European Alzheimer associations provided a more comprehensive outlook of the region, whereas asking individual LTC facilities may have resulted in points that could not be generalized.

For this web-based survey, representatives from 34 National Alzheimer associations of Alzheimer Europe were informed about the study and invited to participate in the survey via a personalized email. With this initial email contact, Alzheimer association representatives were also asked to forward the survey information to their regional Alzheimer association contacts. The researcher (KBB) identified 34 Alzheimer associations’ contacts through publicly available information on their respective websites.

The inclusion criterion for participants was that they spoke sufficient English to understand the study information and complete the web-based survey. Alzheimer associations were given the opportunity to register and provide written informed consent via email. The participants were asked to respond to the survey within 21 days, with email reminders sent every 5 days, and the survey was closed after 28 days. Another reminder was sent out within the extended deadline to solicit additional completed surveys.

Following the first descriptive analyses, we decided to include national LTC expenditure, that is, national funds invested in LTC facilities, as a factor for implementation. We used the data from the Organisation for Economic Co-operation and Development (OECD) to see the national expenditure on LTC facilities measured with current prices in Euro (€) [20]. Consequently, 2 groups of participating countries formed according to their national expenditure on LTC facilities, namely, higher and lower expenditure groups.

The respondents’ countries are as follows: Portugal, Germany, Belgium, France, Netherlands, Norway, Bulgaria, Czech Republic, Finland, Greece, Luxembourg, Malta, Serbia, Slovenia, and Switzerland. Next, we grouped the countries by annual national expenditure on LTC facilities, yielding lower- and higher expenditure groups. National expenditure is the amount of capital invested in LTC facilities by government/compulsory and private/out-of-pocket budgets [23]. Lower and higher expenditure groups (per capita) are defined by the latest OECD values available for all participating countries, which were from 2019 (Multimedia Appendix 1) [24].

Methodological Framework

We used the CFIR [25] to identify barriers to and facilitators of AAL technology implementation. We chose the CFIR because it provides a useful structure for identifying potential factors influencing implementation at multiple levels [25]. The CFIR includes 39 constructs (ie, determinants) organized into 5 domains: innovation characteristics (eg, complexity and strength of the evidence), outer setting (eg, external policy and incentives), inner setting (eg, organizational culture and the extent to which leaders are engaged), characteristics of individuals involved (eg, self-efficacy using AAL technology in a sustainable way), and process (eg, planning and engaging key stakeholders) [25,26]. All constructs interact to affect the process and effectiveness of implementation [25,27]. Therefore, using this framework enables the identified barriers and facilitators to be presented in a structured and systematic manner. It also allows findings to be easily compared to those of other implementation studies to identify research gaps.

Design of the Web-Based Survey

Damschroder et al [25] recommended that researchers try to identify CFIR constructs early on, assess them based on their relevance to the study, and then determine at what level each construct should be measured. In our scoping review [3], we identified 10 of the 39 CFIR constructs as relevant in implementing AAL technology to address loneliness in persons living with dementia in LTC and therefore relevant for our web-based survey:

1. Intervention characteristics
   • Relative advantage: Q1 and Q3
   • Cost: Q5

2. Outer setting
   • Patient needs and resources: Q4 and Q6
   • External policies and incentives: Q13

3. Inner setting
   • Structural characteristics: Q7 and Q8
   • Culture: Q9
   • Implementation climate
     • Tension for change: Q2
     • Compatibility: Q10 and Q11
     • Relative priority: Q12

4. Process
   • Planning: Q14
   • Engaging
     • Key stakeholders: Q15

Our team reviewed and revised the survey, and the final version had 15 questions. Questions were adapted from the CFIR interview guide from the relevant 10 domains identified by the
scoping review. Then, we reviewed the survey and answer choices with an English language expert to ensure suitability for nonacademic staff in Alzheimer associations. Furthermore, we asked 3 Alzheimer associations to pretest and validate the survey for suitability. Two of them responded and gave detailed feedback. We revised the survey accordingly. The survey was then designed in a web-based survey tool (LimeSurvey) [28] and tested for any technical issues.

The web-based survey questionnaire, the recruitment plan, and the deployment plan were extensively discussed with Alzheimer Europe, with whom the researcher (KBB) worked closely using a participatory approach within the project DISTINCT (Dementia: Intersectorial Strategy for Training and Innovation Network for Current Technology), where this study was funded [21]. Alzheimer Europe was involved because they are the most comprehensive union of Alzheimer associations in Europe, and they are one of the collaborative partners of the DISTINCT consortium, which is an EU-funded Marie Skłodowska-Curie research and training project.

**Ethics Approval**

This study received ethical approval from the University of Witten/Herdecke with approval number SR-205/2021. This survey was conducted with ethical principles in mind. In accordance with recommendations for good internet-based research by Gupta [29], the participants were shown an information form and were asked to provide consent before they were able to see the questionnaire. The information form provided complete details of the study, including contact information, study aims, data collection procedure, potential benefits and harms, and steps taken to maintain the anonymity and confidentiality of the participants. These steps enabled the participants to reach out to the investigators and clarify whether they had any questions or concerns. Cookies were used to prevent accessing the survey twice. No personal information about the participants was collected. Survey data were saved in a secure server upon completion and were accessible only to the first author. The participants were informed that they could request to opt-out at any time and could request to delete their records. More detailed information about this process can be obtained from the CHERRIES (Checklist for Reporting Results of Internet E-Surveys) checklist in Multimedia Appendix 2.

**Analysis**

Descriptive statistics were generated using SPSS (IBM Corp) and Excel (Microsoft) [30,31]. The visualization of the data by the balloon plots was performed with the statistical software R (R Foundation) [32], and graphical representations of the data were created with the package ggplot2 [33]. Due to the low response rate (50%), the available data were analyzed using basic statistical methods, and descriptive statistics were calculated. CFIR was used to guide the analysis process [25].

**Results**

**Participants**

This survey yielded 24 full responses across 15 European countries from the 34 national and regional Alzheimer associations across 30 European countries (see Table 1) that were contacted, for a response rate of 50%. Thirty national and regional associations were contacted and 15 responded (15/30 × 100). Organizations in Austria, Croatia, Cyprus, United Kingdom, Denmark, Estonia, Hungary, Ireland, Iceland, Italy, Jersey, Poland, Romania, Slovakia, Spain, Sweden, and Scotland were contacted but did not respond to the survey. For this purpose, we considered both national and regional Alzheimer associations. Therefore, 4 regional responses were added to the national responses.

Two of the participants reported their age group as 18-30 years, 12 participants were between the ages of 31 and 50 years, and 10 were older than 50 years. Seventeen participants were female, 6 were male, and 1 participant was nonbinary. Eleven participants were from national Alzheimer associations, whereas 13 participants were from regional Alzheimer associations. The highest number of responses from 1 country came from Portugal (n=4), followed by Germany (n=3) and then Belgium, France, the Netherlands, and Norway (n=2). The remaining responses came individually (n=1) from the following countries: Bulgaria, Czech Republic, Finland, Greece, Luxembourg, Malta, Serbia, Slovenia, and Switzerland.
Table 1. Participating Alzheimer associations.

<table>
<thead>
<tr>
<th>Answered from a national Alzheimer association</th>
<th>How many answered</th>
<th>National expenditure in LTC(^a) per capita (€)(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulgaria</td>
<td>1</td>
<td>1.3</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1</td>
<td>188</td>
</tr>
<tr>
<td>France</td>
<td>1</td>
<td>417.7</td>
</tr>
<tr>
<td>Germany</td>
<td>1</td>
<td>424.6</td>
</tr>
<tr>
<td>Luxemburg</td>
<td>1</td>
<td>340</td>
</tr>
<tr>
<td>Malta</td>
<td>1</td>
<td>523.3</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1</td>
<td>1047</td>
</tr>
<tr>
<td>Norway</td>
<td>2</td>
<td>705.1</td>
</tr>
<tr>
<td>Portugal</td>
<td>1</td>
<td>28.7</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1</td>
<td>147.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Answered from a regional Alzheimer association</th>
<th>How many answered</th>
<th>National expenditure in LTC(^a) per capita (€)(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>2</td>
<td>474.4</td>
</tr>
<tr>
<td>Finland</td>
<td>1</td>
<td>363.5</td>
</tr>
<tr>
<td>France</td>
<td>2</td>
<td>417.7</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>424.6</td>
</tr>
<tr>
<td>Greece</td>
<td>1</td>
<td>20.6</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1</td>
<td>1047</td>
</tr>
<tr>
<td>Portugal</td>
<td>3</td>
<td>28.7</td>
</tr>
<tr>
<td>Serbia</td>
<td>1</td>
<td>N/A(^c)</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1</td>
<td>816.6</td>
</tr>
</tbody>
</table>

\(^a\)LTC: long-term care.
\(^b\)A currency exchange rate of 1€=US $1.08.
\(^c\)N/A: not applicable.

Perceived Familiarity With AAL Technology Across Europe

Overview

Perceived familiarity is considered a factor affecting the implementation of AAL technology to address loneliness in persons living with dementia. The following sections on perceived familiarity are structured based on types of AAL technology (see Multimedia Appendix 3 for an overview).

Familiarity of AAL Technology and Social Robots

The participants were asked whether they were familiar with the following type of AAL technology with regard to addressing loneliness in persons living with dementia: pet robots, for example, “Paro”; humanoid robots, for example, “Pepper”; multimedia computer systems, for example, “Xbox”; and telepresence robots, for example, “Giraff.” The most familiar pet robot was the baby seal robot “Paro” (n=19), followed only by the “Joy for All” cat (n=6), while 6 participants were not familiar with any pet robots (n=6). Ten of the 15 countries reported having Paro. Humanoid robots were less popular, and the respondents were most familiar with Pepper, as reported by 7 countries. Papero was reported only in Finland. More countries were unfamiliar with humanoid robots than pet robots; 9 of the 15 countries were not familiar with them.

Open-Ended Questions

The participants were asked to manually report any other AAL technology in case the devices that they were familiar with were not on the list. These data are presented as a list of technologies the participants were familiar with (Table 2). One technology that was identified was “Tovertafel.” A gesture-controlled multimedia table was reported by 3 participants, and “KOMP,” a simple tablet computer for video-calling, was reported by 2 participants. The remaining answers were “smart assistants” such as “Siri or Alexa”; “BeleefTV,” a touchscreen on wheels with sensory games and reminiscence; the “Cogweb,” a computer system that provides cognitive exercises; “Smartmacadam,” an app for daily planning; “Music doll,” a therapy doll with a built-in music player; “Easy music player”; and the “Motitech” stationary bike with video. We also asked the participants how they became familiar with these technologies, for example, having direct knowledge of their implementation or having heard about them from other regions or countries. Six participants reported that the technology was actively implemented in their regions, and 5 reported demonstrations...
by the manufacturers, while 1 participant did not report their source of knowledge.

Table 2. Pet and humanoid robots in Europe.

<table>
<thead>
<tr>
<th>Country</th>
<th>Paro</th>
<th>Aibo</th>
<th>JustoCat</th>
<th>JoyforAll Cat</th>
<th>JoyforAll Dog</th>
<th>Paperoa</th>
<th>Peppera</th>
<th>Cuddler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Czech Republic</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Germany</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luxemburg</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Malta</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Netherlands</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Norway</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slovenia</td>
<td>✓</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>✓</td>
<td>✓</td>
<td></td>
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<tr>
<td>Serbia</td>
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<td></td>
<td>✓</td>
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<tr>
<td>Greece</td>
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</tr>
</tbody>
</table>

aHumanoid robots.

**Familiarity With Multimedia Computer Systems**

Fourteen participants were not familiar with any of the multimedia computer systems, whereas 9 participants were familiar with the Digital Lifestorybook. None of the countries were familiar with CIRCA, VENSTER, or ChitChatters. Digital Lifestorybook, on the other hand, was familiar to the respondents in 9 out of 15 countries. Nevertheless, 11 countries reported being unfamiliar with multimedia computer systems. On the other hand, more countries (n=12) were familiar with Nintendo Wii and Xbox than any other options. Although 10 countries were familiar with PlayStation, only 6 countries were unfamiliar with any of the systems (Table 3).

Table 3. Multimedia computer systems by country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Digital Lifestorybook</th>
<th>Nintendo Wii</th>
<th>Xbox</th>
<th>PlayStation</th>
</tr>
</thead>
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Familiarity With Telepresence Robots and Other Technology

Most participants (n=20) reported no familiarity with telepresence robots, with some (n=3) participants familiar with Giraff. The respondents from 13 of 15 countries reported being unfamiliar with telepresence robots. CompanionAble was unknown by all respondents, and the Guide was reported by only 1 participant. Other technologies were reported to be actively implemented only in certain countries. “Cogweb” was reported to be actively implemented in Portugal, “Tovertafel” was reportedly implemented in some care homes in Germany, and “Motitech,” “KOMP,” “The music doll,” and “Easy music player” were reported to be popular in LTC facilities in Norway. Smartmacadam was reported only in France.

Factors Influencing the Implementation of AAL Technology and Social Robots Across Europe

Overview

The participants were asked 15 multiple-choice questions on the factors affecting the implementation of AAL technology in LTC facilities regarding loneliness in persons living with dementia. All questions were fully answered by all participants (n=24). In the following section, the results are presented according to the CFIR implementation domains (see Figure 1).

Figure 1. Survey results by Consolidated Framework for Implementation Research (CFIR) domains. Statistical frequencies displayed by survey questions and CFIR domains. (−−): highly negative; (−): slightly negative; (+): slightly positive; (++): highly positive; IDK: I don’t know.

Innovation Characteristics—Relative Advantage

The participants pointed out that the team atmosphere in an LTC facility influences how care professionals perceive AAL technology and its impact on loneliness (slightly positive=7, slightly negative=8). The team atmosphere concerning the use of AAL technology was reported to be slightly more positive in countries in the lower expenditure group (see Figure 2). Countries in the lower expenditure group reported more advantages of AAL technology in LTC facilities than countries in the higher expenditure group.
Figure 2. Low- and high-expenditure countries’ differences by Consolidated Framework for Implementation Research domains. Frequencies displayed by 2 groups divided by national expenditure on long-term care. Notable differences between low- and high-expenditure countries in Q1: relative advantage; Q2: tension for change; Q3: relative advantage; Q5: costs; Q8: structural characteristics; Q9: culture; Q15: key stakeholders. (−−): highly negative; (−): slightly negative; (+): slightly positive; (++): highly positive; IDK: I don’t know; Q: survey question.

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Innovation Characteristics—Cost

Eight participants reported that AAL technology aimed at loneliness comes with high additional costs, and another 8 reported that they are not aware of the costs. No participants reported that they had no additional costs. The higher expenditure group reported slightly more noticeable additional costs, while the lower expenditure group noted slightly more high additional costs.

Outer Setting—Patient Needs and Resources

Ten participants revealed a somewhat positive attitude among persons living with dementia about AAL technology addressing loneliness, whereas 6 noted a somewhat negative attitude among persons living with dementia. Fourteen participants reported that AAL technology meets some needs and preferences of persons living with dementia, and this response was shared by most participants, making it one of the most agreed-upon subdomains. No participants reported that AAL technology meets no needs at all. The respondents in the lower expenditure group reported a slightly more positive attitude toward persons living with dementia than those in the higher expenditure group. Again, those in the lower expenditure group reported a slightly more positive response regarding the ability of AAL technology to meet more needs than those in the higher expenditure group.

Outer Setting—External Policies and Incentives

Fourteen participants responded that external financial support would definitely increase AAL technology use to address loneliness in persons living with dementia. This response was given by most participants, making it one of the most agreed-upon subdomains. No participants reported that financial support would not increase AAL technology use or that they did not know. Countries in the higher expenditure group reported slightly higher chances of an increase in AAL technology use than those in the lower expenditure group.

Inner Setting—Structural Characteristics

Nine participants revealed that the infrastructure of the LTC facilities corresponds slightly negatively to AAL technology implementation aimed at addressing loneliness, and 5 noted that it corresponds highly negatively. Seven participants answered that there were some building plan changes necessary to implement AAL technology, and 5 noted that many building plans were necessary. The participants from countries in the lower expenditure group reported that the infrastructure of their regions had a slightly more positive impact on implementation than the participants from countries in the higher expenditure group. Additionally, the participants indicated whether they needed any infrastructure changes to implement AAL technology, and the lower expenditure group reported that fewer changes were necessary than the higher expenditure group.
Inner Setting—Culture

Ten participants noted that LTC culture corresponds *slightly positively* with the implementation of AAL technology addressing loneliness, and 9 reported a *slightly negative* correspondence. Two added that they were not aware, 1 reported that it corresponds *highly negatively*, and 2 reported *highly positively*. The lower expenditure group reported that culture corresponds slightly more positively with implementation than the higher expenditure group.

Inner Setting Implementation Climate—Tension for Change

The participants reported how stakeholders, for example, care professionals, persons living with dementia, and informal caregivers, consider the need for AAL technology for persons living with dementia in their region to help decrease loneliness. Nine reported a *considerable need*, 4 reported *only a little need*, and another 5 reported that there was a *strong need*. Countries in the lower expenditure group reported that more AAL technology is needed than those in the higher expenditure group. Countries in the lower expenditure group reported that AAL technology was *needed slightly more* than countries in the higher expenditure group.

Inner Setting Compatibility

The participants reported how well AAL technology fits with the values and norms of stakeholders, for example, care professionals and persons living with dementia in LTC, to address loneliness in persons living with dementia. Eight participants noted that AAL technology *does not truly fit* the stakeholders’ values and norms, 6 revealed that they were not aware, and another 6 noted that AAL technology *somewhat fits* their values and norms. Thirteen participants reported that AAL technology *did not replace* any nontechnological interventions for loneliness, and 6 noted that it *did not really replace* any interventions. Countries in the lower expenditure group reported *higher fit* than countries in the higher expenditure group. When asked whether AAL technology replaced any existing programs for loneliness, both groups reported *no replacement*.

Inner Setting—Relative Priority

When asked about the importance of AAL technology aimed at addressing loneliness compared to other priorities, such as fall prevention, 13 of the participants responded that it was *somewhat important* in comparison to other priorities in the LTC facility. Seven reported that it was *very important*, 3 declared that it was *not really important*, and 1 did not know. No participants reported that AAL technology is *not at all important*. There were no differences between the lower and higher expenditure groups.

Process—Planning

Eight of the participants noted that LTC facilities in their area had *no plan in place at all* to implement AAL technology to address loneliness in their region; 7 had *hardly any plan in place*, 1 had a *partial plan*, and another had *considerable plans* in place. Seven participants were not aware. Lower expenditure countries reflected that they had fewer plans than higher expenditure countries.

Process—Engaging Key Stakeholders

Ten participants reported that Alzheimer associations provided *some encouragement* to the LTC facilities in their regions to implement AAL technology to address loneliness in persons living with dementia, 6 reported that the associations *did not really encourage* LTCs in their area, 4 reported that they *encouraged them highly*, 1 reported that they *did not encourage* LTCs *at all*, and 3 reported no knowledge. The participants were asked whether Alzheimer associations encouraged LTCs in their regions to implement AAL technology, and the higher expenditure group reported *slightly higher* encouragement than the lower expenditure group.

Additional Factors

According to OECD data [23], national expenditure on LTC facilities appears to be a factor that might mitigate the familiarity of AAL technology in a given country or region. It also appears that Northwestern European countries are familiar with more AAL technology than Southeastern European countries. This can be observed in the expenditure on LTC facilities (see Multimedia Appendix 1).

Discussion

Principal Findings

In this survey, we investigated familiarity with AAL technology in Europe and the factors influencing the implementation of AAL technology in LTC. We have found that the seal pet robot Paro was the most familiar AAL technology being used to address loneliness in persons living with dementia across Europe. Pet robots were more familiar than other types of AAL technologies. The least familiar AAL technology was telepresence robots. Survey respondents were on average familiar with 7 AAL technologies, ranging between 14 and zero.

Comparison to Prior Work

The literature suggests an array of implementation barriers when implementing AAL technology in LTC to address loneliness in persons living with dementia, such as user capabilities, user willingness, and family support [34]. In this paper, we investigated the perceptions of European Alzheimer associations regarding implementation barriers. Those countries in the lower expenditure group appeared more accepting toward AAL technology implementation in LTCs, in accordance with previous research [35]. At the same time, the respondents from these countries reported being familiar with fewer technologies. The participants from countries in the higher expenditure group generally reported less acceptance, more disadvantages, less fit with norms and values, and less interest from persons living with dementia. This group also reported being familiar with a higher number of technologies. It seems that the fewer technologies a country has, the higher the interest in more technology. This may be due to the active experience of the implementation phase, where care professionals experience the implementation barriers first hand. For example, in Spain, a lower expenditure country, it was found that the effective use of AAL technology could allow care professionals to spend more time on social intervention and less on administrative tasks [35]. Despite hardships, care professionals displayed an
optimistic point-of-view toward AAL technology [35]. However, in Norway, implementation of a social communication tool (KOMP) changed work routines and created additional responsibilities for care professionals [36]. Even though care professionals tried to come up with creative ways to motivate persons living with dementia, using KOMP was limited by the physical and cognitive abilities of its users [36]. This is a novel finding considering the lack of studies in the literature focusing on lower expenditure countries [35] and a number of studies focusing on higher expenditure countries [34,36,37].

In Germany, a higher expenditure country, lower acceptance of Giraff in persons living with dementia was found to be linked to the lower psychological well-being and lower cognitive abilities of residents, unlike the case of Paro [38,39]. This could be explained by the lower cognitive requirements of using Paro as opposed to using more complicated technologies such as Giraff. Additionally, in Germany, using digital technology for social engagement increased 72.8% (n=349) during the COVID-19 pandemic [34]. However, relatively slow uptake of the technology by residents with dementia due to the absence of adequate support from staff and the lack of staff training were indicated as barriers to implementation alongside costs [34]. This confirms our finding on the critical stance of higher expenditure countries toward AAL technology not meeting many needs of residents and not fitting with existing workflows.

In the United Kingdom, a high-expenditure country, technological illiteracy, the low technological confidence of staff, and persons living with dementia being distressed by the robotic voice of the device were reported as barriers to implementing smart speakers in LTC facilities [40]. In Ireland, another high-expenditure country, interviews with care professionals revealed that costs, lack of personnel, and concerns about meeting the needs of persons living with dementia were perceived barriers to the implementation of social robots in LTC facilities [41].

The findings of a review that included studies from the United Kingdom, the Netherlands, Finland, and Sweden suggest that persons living with dementia can potentially benefit from using digital technologies such as videoconferencing to help them maintain and create social networks [37]. However, the usability of the technology, supporting individuals in using the technologies, and training the family caregivers are issues that need further research [37]. Higher expenditure countries seem somewhat more experienced but also more critical toward the implementation of AAL technology. Therefore, this survey confirms the literature findings on the higher expenditure countries’ critical stance on AAL technology implementation due to, but not limited to, concerns about costs, staff resources, the technological illiteracy of staff, and the cognitive abilities of residents.

Based on our findings, we argue that there is no direct link between the funds spent on AAL technology in LTC and the satisfaction gained from it for both residents and staff. The technological literacy of both staff and residents seems to play an important role in implementation. Care practitioners need to match the needs of the residents and staff with the functionality of the AAL technology. Policy makers are likely to benefit from facilitating a dialog with stakeholders involved in co-design [42] and co-research [43] efforts in dementia and in AAL technology, approaches that are becoming increasingly relevant both in practice and in research.

Study Limitations

First, the staff involved in implementing AAL technology in nursing homes were not included in the sample. This may have affected the results in such a way that we might not be informed about the first-hand experiences of AAL technology implementation. The survey inquired about only participants’ perspectives on factors potentially influencing AAL technology implementation and the status quo of AAL technology implementation in relation to addressing loneliness in persons living with dementia based on their expertise as regional or national dementia organizations. Including LTC facilities in different European countries in the web-based survey could have provided first-hand perspectives on the implementation of AAL technologies, in addition to the broader picture provided by Alzheimer associations. However, the expected effort needed to obtain contact data, translate the survey into different national languages, and obtain a representative sample of LTCs outweighed the expected added value given the available time and human resources.

In addition, the original names of the AAL technologies were used as in the scoping review prior to the survey. However, the authors point out that some of the technology might have been known by other names in the field of LTC. For example, a multimedia technology, ChitChatters, is also known by the Dutch name “de Klessebessers.” This might have impacted the familiarity of the respondents with this particular AAL technology.

Additionally, familiarity with AAL technology was explored in the context of addressing loneliness in persons living with dementia in LTC, whereas the survey respondents might have considered a certain AAL technology as familiar for other reasons, such as personal usage.

Furthermore, the respondents from 5 of the 7 countries in the lower expenditure group reported familiarity with the multimedia computer systems Xbox, PlayStation, and Nintendo Wii. This result must be taken with caution due to the worldwide availability of these devices for various contexts. These devices are known throughout the world for video gaming, and there are no data showing that they are known in LTC settings specifically and not from personal entertainment experience.

Finally, the sample size was small (N=24), which can be seen as a factor that limits the generalizability of the results. It was also somewhat unbalanced, with some countries being more represented than others. The same applies to the representation of national and regional associations within the countries.

Conclusions

Paro was found to be the most familiar AAL technology, and telepresence robots were the least familiar. Northwestern European countries were familiar with more devices than Eastern and Southern European countries. This finding corresponds with the national LTC expenditures of participating countries [20].
It seems that the expenditure of European countries on LTC facilities might be linked with the number of AAL technologies their citizens are familiar with. The respondents from higher expenditure countries reported that they encourage their associations to implement AAL technology in their areas more than those in the lower expenditure group, despite their critical stance toward AAL technology. Future research is needed to clarify the potential reasons why LTC expenditure is not linked with acceptance, attitudes, or satisfaction with AAL technology in LTC.

European Alzheimer associations generally seem to agree that AAL technology meets only some needs and preferences of persons living with dementia; that AAL technology is somewhat more important than other priorities in LTC facilities, such as fall prevention; and that external financial support would increase AAL technology use to address loneliness in persons living with dementia.

Finally, the attitude of stakeholders seems to have a more positive impact in lower expenditure countries. Therefore, further research is needed to extend and diversify the role of AAL technology in addressing loneliness in persons living with dementia.

Acknowledgments
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Conflicts of Interest
None declared.

Multimedia Appendix 1
Participant countries’ long-term care (LTC) expenditure per capita.
[PNG File, 34 KB - aging_v6i1e45231_app1.png]

Multimedia Appendix 2
CHERRIES (Checklist for Reporting Results of Internet E-Surveys).
[PDF File (Adobe PDF File), 174 KB - aging_v6i1e45231_app2.pdf]

Multimedia Appendix 3
Active assisted living technology per country.
[DOCX File, 14 KB - aging_v6i1e45231_app3.docx]

References


22. About INDUCT. INDUCT. URL: https://www.dementiainduct.eu/about/ [accessed 2023-05-18]


Abbreviations

AAL: active assisted living
CFIR: Consolidated Framework for Implementation Research
CHERRIES: Checklist for Reporting Results of Internet E-Surveys
DISTINCT: Dementia: Intersectorial Strategy for Training and Innovation Network for Current Technology
LTC: long-term care
OECD: Organization for Economic Cooperation and Development

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Strengthening Social Capital to Address Isolation and Loneliness in Long-Term Care Facilities During the COVID-19 Pandemic: Systematic Review of Research on Information and Communication Technologies

Idrissa Beogo¹, RN, MBA, PhD; Drissa Sia², MD, PhD; Stephanie Collin³, PhD; Andi Phaelle Gedeon¹, BSc; Michaël-Christopher Louisme¹, BSc; Jean Ramdé⁴, PhD; Marie-Pierre Gagnon⁴, PhD; Eric Tchouaket Nguemeleu¹, PhD

¹University of Ottawa, Ottawa, ON, Canada
²Département des sciences infirmières, Université du Québec en Outaouais, Saint-Jérôme, QC, Canada
³Université de Moncton, Moncton, NB, Canada
⁴Université Laval, Quebec, QC, Canada

Corresponding Author:
Idrissa Beogo, RN, MBA, PhD
University of Ottawa
200 Lees Avenue
Ottawa, ON, K1N 6N5
Canada
Phone: 1 6135625800 ext 8148
Email: ibeogo@uottawa.ca

Abstract

Background: The COVID-19 pandemic has disproportionately and severely affected older adults, namely those living in long-term care facilities (LTCFs). Aside from experiencing high mortality rates, survivors were critically concerned by social isolation and loneliness (SIL). To address this serious public health concern and stay connected with LTCF residents, information and communication technology (ICT) platforms (eg, video calls) were used as an alternative to maintaining social interactions amid the visiting restriction policy.

Objective: This paper aimed to synthesize the effects of ICT-related communication interventions using SMS text messaging or chat, video, voice mail, or photo to address SIL in LTCF residents during the COVID-19 pandemic.

Methods: In total, 2793 references published in English and French in 2019 and onward were obtained from 10 relevant databases: PsycINFO-Ovid, Ovid-MEDLINE, CINAHL-EBSCO, Cochrane Library, Web of Science, Scopus, DirectScience, Communication & Mass Media Complete, IEEE Xplore, and ACM Digital Library. A 2-person screening approach was used, and the studies were screened independently and blindly. A narrative synthesis was performed to interpret the results of the included studies, and their quality was appraised.

Results: In total, 4 studies were included in the review. ICT-related applications were used to ensure connectedness to address SIL. ICT interventions consisted mainly of videoconferencing, intergroup video call sessions between residents, and chatting (SMS text messages and phone calls). Roughly 3 classes of mediating ICT tools were used: video calls using software applications (eg, Skype); robot systems embedding video telephones; and ordinary telecommunication such as telephone, internet, social media platforms, and videoconferencing. This review has included the role of humanoid robots in LTCFs as an innovation avenue because of their multipurpose use (eg, communication tools and remotely operable).

Conclusions: Remote social capitalization through ICT applications has become an avenue to reduce SIL among LTCF residents. This review examined a social connection approach that will remain relevant and even be fostered after the COVID-19 pandemic. As families remain the main stakeholders of LTCFs, this study’s findings could inform policy makers and frontline managers to better shape programs and initiatives to prevent or reduce SIL in LTCFs.

International Registered Report Identifier (IRRID): RR2-10.2196/36269
**Introduction**

**Background**

The COVID-19 pandemic has caused extreme loss of life, especially in long-term care facilities (LTCFs). We can acknowledge that this global crisis disrupted the entire health care sector. In Canada, LTCFs house 6.8% of people aged ≥65 years [2]. Health care systems experienced an unprecedented crisis. Approximately 80% of deaths occur in the long-term care (LTC) sector, with Canada being among the worst performers, with a rate double the average death rate of the Organization for Economic Co-operation and Development countries’ mortality (42%) [3]. In response to the spread of the COVID-19 pandemic, tight visitation restrictions were levied, isolating the LTCFs from the rest of the community, subsequently isolating older adults, already fraught with the morbidity of social isolation and loneliness (SIL) [4,5]. These measures removed the main sources of support (care, social, etc) provided in the pre–COVID-19 era by informal family caregivers (FCs). Consequently, to address the SIL induced by the lockdown on older adults, almost all previous in-person interactions with older adults were replaced by web-based chatting using information and communication technology (ICT) applications, such as FaceTime, Zoom, and Microsoft Teams video chatting.

A wealth of literature has demonstrated that SIL is negatively associated with several adverse outcomes, such as teeth loss acceleration as reported in a longitudinal study [6], risk of premature mortality [7], and mental health disorders (eg, depression and anxiety) [8], to cite a few. Before the pandemic, the importance of families’ partnership with the health care sector was well-documented. Strong family or community support is essential to maintain social ties with families, friends, and the community at large [9,10]. Approximately one-fifth of families directly care for their older adults [11]. The pandemic has been associated with worsening SIL, which preexisted at a rate of ≥40% [4,5]. It also appears that most older adults are unenthusiastic about leaving their community home to move to an LTCF [12,13]. Many residents who experience marginalization associated with sexual orientation—4% of the general population [14]—or race (Black, Asian, etc) or religion (eg, Muslim) possibly faced more SIL during the pandemic.

ICT applications have been overwhelmingly used as an innovative alternative avenue to stay in touch with loved ones and bolster resilience to increasing SIL worsened by the pandemic’s restrictions. Therefore, families substituted their traditional face-to-face visits with virtual visits (video calls, phone calls, chat, or photo posting) [15,16]. This initiative was welcomed, although the Canadian system’s LTCFs are poorly equipped with IT infrastructure. Indeed, LTCFs operate outside of the Canada Health Act, which provides universal access, public funding, and transferable physician care in hospitals [17].

In contrast, LTCFs operate to meet social needs as opposed to medically necessary needs. Social activities (bingo, painting, outings, walks, etc) that were traditionally conducted in person [18] were consequently suspended during most of the pandemic. In addition, some authors have stated that video interactions showed effectiveness in terms of learning, and stimulation of cognitive activity [19] as well as knowledge transfer [20]. ICT has emerged as a promising, new, and innovative avenue for maintaining social connections. Unfortunately, some studies highlight the lack of technological literacy among older people and their families [21]. The use of ICT to reduce SIL has been extensively studied, even in the pre–COVID-19 pandemic era [22,23]. These studies included the effects of internet-based interventions [24-26] and humanoid robot approaches [27]. However, systematic reviews on remote interventions are still undecided regarding the positive outcomes of social loneliness. Nevertheless, we have witnessed an increased use of ICT applications—from the conventional telephone to web-based platforms, such as Skype, FaceTime, Zoom, or Google Meet. Banskota et al [28] have identified 15 types of applications—social networking (FaceTime and Skype), medical telemedicine (Teladoc, K health, and Doctor on Demand), medical prescription management (GoodRX and Medisafe Medication Management), health and fitness (Calm, Headspace Medication and Sleep, Yoga Down Dog, and MyFitnessPal), food and drink (DoorDash and Instacart), and visual and hearing impairment (Be My Eyes Helping the Blind and Glide)—that older adults have used during the COVID-19 pandemic. Chen and Schulz [29] underscored the ones used by families to interact with their loved ones in LTCFs as well as with the LTCF staff members because of the rising incidence of COVID-19 cases and associated visitation restrictions.

As the population ages worldwide and the family size decreases, SIL is becoming an increasingly pertinent public health issue. In Canada, according to the International Federation on Aging, keeping older people socially connected and active is a challenge [30]. In the past decade, many high-income countries have implemented large-scale programs to address the growing concern that SIL poses in societies [31-35]. The estimated cost of voluntary work by FCs a decade ago was valued at approximately CAD $25-$26 billion in Canada (a currency exchange rate of CAD $1=US $0.76 is applicable) [36]. In a 2012 study, 22% of caregivers provided 10 hours a week of personal care for older adults in collective dwellings [11]. This shows how FCs remain an essential labor force in the health care system. For example, for older Canadian adults living with complex conditions, frailty, and impairments, FCs provide up to 70% to 90% of the care [37].

Before the COVID-19 pandemic, reviews were conducted to demonstrate the impact of ICT on addressing SIL in LTCFs. Although the most recent Cochrane rapid review [22] did not prove a conclusive advantage, an earlier systematic review
Inclusion and exclusion criteria were based on the PICO framework. Inclusion and Exclusion Criteria

Inclusion criteria, the study should include people aged ≥65 years and those residing in an LTCF that is a congregate institutional arrangement setting (eg, nursing homes or assisted living arrangements). Exclusion criteria included studies of people (1) with a terminal illness, (2) who were hospitalized, (3) who had severe neurocognitive disorders, (4) with severely impaired cognition (measured by specific tools, such as the Mini-Mental State Examination) [44], or (5) who were community dwellers.

Research Questions and Objectives

This review intends to assess the effects of ICT interventions implemented in LTCFs to address SIL among residents during the COVID-19 pandemic. The following objectives will be considered to address the research question:

1. To synthesize the effects of ICT-related communication interventions to address SIL in LTCF residents during the COVID-19 period.
2. To identify studies that use ICT, namely through various means of communication, such as texting or chat, video, voice mail, or photo, as a strategy for interaction and connection with older family members living in LTCFs.

Methods

Overview

We used a comprehensive and current database to catalog the literature on the use of ICT interventions to address SIL during the COVID-19 pandemic crisis. This systematic review considered world literature, and the selected criteria were based on a scrutiny framework (Population, Interventions, Comparators and designs, Outcomes [PICO]) and a robust search strategy. The review protocol was registered at Open Science Framework [40]. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was implemented to provide all relevant information related to the systematic review [41]. We adhered to the Cochrane Collaboration guidelines [42]. The Synthesis Without Meta-analysis guideline [43] was consulted to guide the use of alternative synthesis methods.

Types of Participants

This systematic review included studies dealing with older adults living in any form of congregate institutional arrangement settings, such as nursing homes, municipal homes for older adults, and charitable homes for older adults. As per the inclusion criteria, the study should include people aged ≥65 years without severe mental illness.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were based on the PICO framework.

Population

The inclusion criterion was studies including participants aged ≥65 years and those residing in an LTCF that is a congregate institutional arrangement setting (eg, nursing homes or assisted living arrangements). Exclusion criteria included studies of people (1) with a terminal illness, (2) who were hospitalized, (3) who had severe neurocognitive disorders, (4) with severely impaired cognition (measured by specific tools, such as the Mini-Mental State Examination) [44], or (5) who were community dwellers.

Intervention

As this systematic review targets the use of information technology applications, we included video, voice mail, photo, or any form of chat using any commercial applications (eg, TikTok, FaceTime, Facebook, and Zoom) for conversation through a digital tool (eg, computers, smartphones, or tablets). These accommodations help maintain or improve the connection between families and their older loved ones residing in an LTCF with the ultimate goal of combating SIL. The main ICT intervention component had to involve the use of the internet to fulfill social networking needs. We also considered the standard telephone use. The interventions had to be delivered individually or in a collective format. We excluded any form of digital accommodation requiring an important face-to-face discussion component or telecommunication for medical assessment and treatment.

Comparator and Designs

This study included quantitative design studies, namely quasi-experimental studies, cohort studies, cross-sectional studies, randomized controlled trials, quasi-randomized controlled trials, and pre-post intervention studies. Qualitative and mixed methods studies were also targeted. Studies that compared ICT interventions with alternative interventions, such as visits through windows or contactless control groups during the pandemic, were included. As planned in the protocol [45], all ICT-based therapeutic interventions such as telehealth or telemedicine, as defined by the World Health Organization [46], were also excluded. Further comparisons among virtual technology–enabled groups such as telephone versus video calls were included.

Outcome

Primary Outcomes

The primary outcomes were as follows:

1. Measures of SIL (ie, scores on any qualitative appropriation)
2. Measures of SIL through proxy outcomes (ie, the lack of companionship, the lack of friendship, a feeling of being forgotten and not belonging, and the lack of connection with family)

Secondary Outcomes

The secondary outcomes were as follows:

1. Self-reported measures of symptoms of depression (ie, scores on any self-report questionnaire designed to quantify the severity of depression symptoms)
2. Self-reported measures of quality of life (QOL; ie, scores on any self-report questionnaire designed to allow people to rate the QOL either overall or within specific domains)

**Timeline**

This study covered publications completed since the onset of the COVID-19 pandemic from December 2019 onward.

**Data Source and Search Strategy**

An exploratory search of the MEDLINE database was first performed to scan for titles, abstracts, keywords, and descriptors. Subsequently, the complete search strategy was developed to shape each database’s specificities accordingly. We used an iterative process to enhance the search strategy and adjusted the search results for each database to help capture all potential studies.

Multimedia Appendix 1 presents the final search strategy that consists of the following databases: PsycINFO-Ovid, Ovid-MEDLINE, ACM Digital Library, CINAHL-EBSCO, Cochrane Library, Web of Science, Scopus, DirectScience, Communication & Mass Media Complete, and IEEE Xplore. The final search of the Chinese databases planned in the protocol was inconclusive (CNKI, WanFang, Weipu [VIP], and SinoMed). Finally, we only considered studies published in French and English from these databases.

**Study Selection and Data Extraction**

All records from the queried databases were first transferred to the EndNote package, where duplicates were removed electronically and manually and then transferred to the Rayyan web platform [47]. We implemented a 2-person screening approach, in which 2 research assistants and coauthors (APG and MCL) independently screened the titles and abstracts of potentially eligible studies. A structured algorithm (Figure 1) developed and implemented by IB, DS, and ETN in previous studies was used to support the process. Finally, conflicts were solved by the principal investigator (PI) IB.

**Figure 1.** Screening Algorithm.

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**Data Extraction**

APG proceeded with data extraction under the supervision of the PI. This was preceded by a pilot test with the PI. A Microsoft Excel spreadsheet was used to analyze the data extracted. For each publication included, systematic data extraction was performed to summarize (1) the objectives, (2) the intervention objectives, (3) the participants’ characteristics, (4) the experimentations (technology used and duration), (5) the method of the study (study design, inclusion of a control group, and the assessment tools used), (6) the barriers and enablers to the implementation of the technology, (7) the benefits of the intervention on social interactions, and (8) the solutions to overcome barriers to the implementation of the technology (Multimedia Appendix 2).

**Data Analysis and Synthesis**

The analysis consisted of identifying relevant data or segments of data linked to the objective of the review in each article. For qualitative-like study used, findings were organized according to the purpose of the use of ICT-related applications, the feelings of older adults regarding the applications, and their impact on their relatives. A thematic approach was used to identify themes from the presented data. Because the study explored a better understanding of users’ experiences, we used a descriptive phenomenological approach [48] and thematically dealt with data analysis because of the high flexibility of this approach.
We considered inductive coding to determine the final themes. A recurring emergent pool of subthemes derived from data was consensually retained as main themes, either naturally or aggregated based on the objectives and prevalent literature. No theme categories were preset. Finally, 6 main themes were considered: (1) the focus area of the technology, (2) the use of the temi robot (Medisana GmbH), (3) the use of ordinary telephone versus the use of video call, (4) virtual remote communication, (5) effects of technology on SIL, and (6) effects of technology on other outcomes. Analyses were performed manually. Subsequently, a thematic analysis was performed.

Ethics Approval

As this systematic review is part of the Social Isolation and Loneliness project, we received ethics approval from the Ethics Committees for Research of the University of Ottawa (H-08-21-7314), the University of Moncton (dossier 2021-073), and the Research Ethics Board of the Primary Care and Population Health Research Sector of the Centre intégré universitaire de santé et de services sociaux de la Capitale-Nationale (2021-2303_SPPL).

Results

Overview

The flow diagram illustrated in Figure 2 illustrates the selection flow of the initial yield of 2793 articles. The screening of titles in the abstracts led to 49 studies. Their plain texts were read for further eligibility assessment. Finally, 4 studies were retained for the review. The list of excluded publications (n=45) and the reasons for exclusion are provided in Multimedia Appendix 3. We excluded records that are not focused on settings other than LTCFs. We also excluded records that discussed interventions other than ICT-related applications to address SIL.

Studies were conducted in Germany, the United States, France, and the United Kingdom. The following different types of LTCFs were included: nursing homes, LTC homes, and assisted living facilities.

The following designs were used in this study: implementation study, observational trial, collaborative action research, and cross-sectional study. The included studies reached 349 participants ranging from 22 to 132. Several study designs were included in this review and are detailed in Multimedia Appendix 2. We organized the findings of the included studies into themes and further grouped them into natural clusters around certain topics, that is, we identified the following three key promising best practices themes: (1) strategic approach, (2) COVID-19 prevention-related interventions (primary and secondary), and (3) COVID-19 free interactive.
**Intervention Type**

Numerous types of social-oriented applications were implemented in this review. This includes roughly the use of the ordinary telephone and a variety of platforms for social conversation, that is, in the included studies, the authors dealt with the following platforms: video calls using software, such as Skype, Zoom, and FaceTime [54]; robot temi embedding videotelephony [52]; telephone or video [39]; and desktop computers, laptops, tablets, smartphones, the internet, social media platforms, and videoconferencing [55].

**Focus Area of the Technology**

Several types of tools mediating conversations between families and older adults were used in the included studies. The first category of implementation studies in which the intervention object was implemented for 2 to 8 months included Skype [52] and several other types of commercial applications such as FaceTime, Skype, and Zoom [54]. The second batch of studies used a cross-sectional approach to portray the use of ICT-based applications in the context of COVID-19 by older adults to maintain the connection between families and LTCF residents [39,53]. Finally, a third group included the use of robot technology incorporating remote communication systems through video telephony.

**Use of the temi Robot**

Follmann et al [52] implemented the use of robots to establish connections between families and residents. These robots have some features that allow the residents to establish connections with relatives through embedded Skype applications. temi served as a companion to the residents. A comparison was made between the 2 study sites. The use of temi resulted in a significant decrease in loneliness compared with the control group, in which residents had no contact ($P=.01$). Several benefits have been demonstrated with the use of temi. For residents, temi’s implementation advantage extends beyond social networking mediation. Because of its autonomy, it rules out the risk of infection with controllable and comfortable operating features (comfort and quality of voice), to cite a few. For relatives, it allows for the continuity of contact with both residents and nursing staff. The absence of financial burden and the risk of infection were also reduced with the implementation of this robot. For the nursing staff, temi offered direct contact with relatives. The possibility of having temi autonomously in a quarantine room, the absence of a need for its supervision, and its ease of disinfection were all factors that facilitated its adoption by the staff.

**The Use of Ordinary Telephone Versus Video Call**

The study by Sacco et al [39] compared the use of telephones by older adults in LTCFs versus acute geriatric care. Older adults in an acute geriatric care unit, LTCF, and nursing home found it easier to use a telephone independently compared with video-enabled technology (video calls). Participants reported ease of use of the telephone (73/132, 55.3%) compared with video calls (59/132, 44.7%). Moreover, patients hospitalized in the acute geriatric care unit were more often satisfied with video communication (73/79, 92%) than residents of the LTC and nursing homes (20/27, 74%; $P=.02$), although the latter’s satisfaction experience with video calls was still high.

**Virtual Remote Communication**

The study by Schuster and Cotten [53] reported high rates of benefits of socializing virtually with family members (26/34, 77%) and friends (16/34, 47%). However, barriers were identified, such as time to assist residents with the technology, issues related to device maintenance and repair, and residents’ fear of sharing communication devices because of possible contamination (9/34, 26%).

**Effects of Technology on SIL**

The study by Zamir et al [54] focused on intergroup video call sessions between residents of 3 care homes and demonstrated that video calls for socialization helped residents to “pass the time,” and gave them “something to do.” The themes generated included feelings of happiness, having a space for expression, and other social activities that allowed older adults to fill their spare time. The following excerpts demonstrate the use of ICT and the expressive feelings of older adults during the COVID-19 pandemic on the topic of their social life. First, the LTCF managers aimed to switch the social activity from in-person (before the COVID-19 pandemic) to a virtual format with an interesting consequence. The following excerpt is an illustration of residents expressing their feelings of happiness: “...With this (quiz), we spoke about our lives and even when I used to live in the country because [resident] also did. I got to share with them... someone new who is happy to hear!” In addition, the following resident from the same study [54] laid out the fact that remote communication in such a situation gave them an opportunity to chat and beyond to share their memories, as portrayed in the following quotation:

*When I first came across ... it was amazing ... felt like such an expert! This box was able to communicate from up there ... but now yes it is similar but the technology has changed. Had we been able to see faces then ... well I doubt we could have it was too old.*

Another resident added:

*Good to see them face-to-face, something to do ... I know it’s not good to speak to people you don’t know ... but ... she’s a talker. Maybe it’s good to use on certain occasions when with friends something to see. I don’t have a house or wife and the years go by now.*

**Effects of Technology on Other Collateral Outcomes**

The use of the temi humanoid robots in the Follamn et al [52] study showed the importance of this technology for every group, including families, staff members, and older adults. temi’s main purpose is to reduce SIL through chatting. It can be remotely driven; therefore, this technology can reduce some communicable diseases by reducing infectious contact between the staff members and LTCF residents. temi also offers the possibility of being autonomous in a quarantine room, does not require supervision, and is easily disinfected. Finally, temi was seen to be a useful tool for employees in the study by Follmann et al [52].

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Quality Appraisal

To address the variation in study designs, we appraised the quality by using the Specialist Unit for Review Evidence (SURE) critical appraisal checklists [36], as reported by other authors [37]. All 12 items were critically considered to offer an in-depth appraisal of quality. We found it useful to portray the quality of all the components of each study (Multimedia Appendix 4 [39,52-54]). Of these studies, one lasted 78 days [52] and another lasted 8 months [54]. The 4 included studies [39,52-54] used a quantitative and participatory design. All studies implemented nonprobabilistic sampling. Studies unclearly reported participant sampling, and their size was insufficiently described. None of the 4 studies reported any attempt to blind participants from the intervention outcomes being examined or disclose information about whether assessors were aware of the intervention. Only 1 study [52] included a control group; Zamir et al [54] presented a control-like group, and 2 studies used a cross-sectional design [39,53]. The authors did not explain how a certain location, nursing home, or community was selected and why. Finally, although the studies mentioned the number of participants, none of them described how the study size was determined.

Discussion

Principal Findings

We found that ICT-related applications were used to ensure connectedness in addressing SIL in LTCFs during the COVID-19 pandemic. There were 3 main categories of ICT: (1) video calls; (2) robot systems; and (3) ordinary telephone, internet, and social media platforms.

To date, SIL is known to be one of the most prevalent issues associated with the aging population trend [58]. This systematic review aimed to portray the available evidence of ICT use in addressing SIL in LTCFs during the COVID-19 pandemic compared with SIL in the long term before the pandemic [59]. Overall, 4 studies were included [39,52-54].

On the basis of the results of this review, we can acknowledge that few studies have been published so far on the topic of ICT use in LTCFs in the context of COVID-19. There is wide heterogeneity in the quality of the studies assessed by the SURE checklist, possibly because of the complex nature of the proposed tool, the design, the duration of the implementation, or the weak sample size.

As stated by Seifert et al [60], the COVID-19 pandemic has incurred a double burden for the residents of LTCFs. First, a large proportion of them were naturally excluded from digital services because of technological illiteracy or their lack of necessary devices and network connectivity [60]. When considering the included studies, there was a clear positive outcome in the few proposed tools in terms of addressing SIL [52,54].

The use of digital tools is a new paradigm for older adults, notably those located in LTCFs, as most of those being relocated to these congregate settings are either older in age or living with disabling comorbidities [61]. Therefore, they tend to have more comorbidities and frailty, affecting their ability to engage with digital tools or learn new associated competencies. Notably, dementia, which affects praxis, language, knowledge acquisition, and mood, is highly prevalent among LTCF residents [62]. Apart from these challenges, our results have shown that some older adults remain averse to digital technology, preferring to use an ordinary telephone [63]. The use of available telephones to reach out to families of older adults, according to the US federal government policy, is mandatory. In several studies [64-66], preference was given to the ordinary telephone to take news of residents. This reluctance might be associated not only with the perception of the complexity of digital tools [67] but also with the resistance to change [68] and difficulties adjusting to change with advancing age and prevalence of cognitive decline. Another reason highlighted in the literature is that, in the context of some group activities with coresidents, some older adults have expressed discomfort and reluctance to open their camera [54].

All these aspects must be considered in the future. First, current older adults face e-technology issues that are overwhelming whereas other older adults are enthusiastic about adopting technology even with limited skills. Growing older tends to be associated with limited digital literacy, but baby boomers are now approaching old age. Worldwide, baby boomers reach retirement age and work longer [69,70] with innovative labor market policies that prolong the working period [71]. Second, as shown in the review, the use of digital technologies is rapidly emerging as an important avenue in LTCFs. Humanoid robot technology is a new innovative avenue for geriatric institutions [72] with multiple purposes, offering live interactions, games, and other friendly companionship features. More research is currently being conducted in Japanese laboratories in the field of robotics to improve human well-being, particularly in old age. They are fraught with a simultaneous risk of 2 major issues: social isolation and nursing care personnel shortage. The avenue of robot technology offers recreational programs to promote communication among older adults in LTCFs [73]. Recreational activities, almost the core activity in an LTCF, subsequently improve the QOL of older adults. Nevertheless, the consequences of robot implementation require upfront capital investment in human resources, equipment, and infrastructure. Overall, the current results on the humanoid robot avenue are beneficial for older adults [73].

In the LTCFs, the added value of the humanoid robot goes beyond serving as a communication tool between older adults and their families. It could also mitigate the risk of communicable disease transmission, as discussed earlier, and can be remotely incorporated. Nevertheless, digital technology is accompanied by limitations. For example, those with dementia tend to have problems with digitally implying tools [15].

This review did not strictly adhere to standard Cochrane methodology. We did not consider gray literature, preprints, conference abstracts, and proceedings. Although the literature published in English and French was included, we recognize the limitations associated with the fact that we ignored publications in other languages (eg, Chinese, Portuguese, and Arab and North Germanic languages). We also planned to exclude hospitalized older adults from the study. However, the study by Sacco et al [39] was retained by the research team.
because the participants belonged to the same institution (geriatric acute care unit and in the LTC unit and nursing home, University Hospital of Angers, France). Finally, the review included very few studies, despite the tremendous scientific productivity of the COVID-19 pandemic. We hypothesized that many projects are ongoing.

**Recommendations for Policy, Practice, and Future Research**

Although heightened during the pandemic, SIL was a pervasive issue in LTCFs in the pre–COVID-19 pandemic era. The findings of this study have important implications for older adults’ QOL agenda for first-line managers in LTCFs and policy makers. Indeed, ICT-related application use offers a convincing perspective for strengthening social connections between families and their loved ones to reduce SIL. The latter is a serious public health concern, such that maintaining LTCF residents’ social capital, namely social sustained connection, is paramount to their QOL. Moreover, ICT platforms (eg, video calls) offer practical means in the post–COVID-19 pandemic era to mitigate the consequences of SIL. Information technology infrastructures (eg, the internet) are acutely lacking—in Canada, for instance [74]—and are therefore needed in 24-hour residential LTC (herein nursing homes in Canada) as defined by Health Canada [75]. Besides crises such as the COVID-19 pandemic, seasonal influenza and gastrointestinal virus outbreaks in nursing homes are very common [76] and often lead to visit bans, although socialization must continue remotely because the goal of LTCFs’ care is to prioritize QOL. This includes QOL at the end of life, avoidance of distress, transfers to the hospital, invasive investigation and interventions, and peaceful death. Because of the lack of available studies, more research is needed to update these review findings and validate the effectiveness of ICT-related applications in combating SIL in LTCFs.

**Conclusions**

To the best of our knowledge, this study is certainly one of the first systematic reviews examining the effect of the use of ICT social applications for the purpose of reducing SIL in LTCFs during the COVID-19 pandemic. Undoubtedly, virtual communication has become a new avenue for connecting people, particularly those more at risk of SIL. This is the case for older adults who relocated to congregate settings. It has been the forefront tool used by families to keep in touch with older adults in LTCFs throughout the multiple lengthy and deadly waves of the COVID-19 pandemic. Not reiterating the potential issues of e-technology, some powerful improvements, such as humanoid robots, are coming to the ground. The review has shown positive effects in terms of social connectivity, as well as acceptance by staff members who value its potential to mitigate infectious contact because of its ease of disinfection.

The findings of this systematic review draw attention to the relevant stakeholders of health systems, notably those involved with LTCFs, to address SIL as an urgent and emerging public health issue. This review, the first of the COVID-19 pandemic era, is an initial step to inform policy makers of the need for higher-quality programs for interventions addressing SIL with a special place given to virtually and technologically enabled social interactions. SIL is a socially complex concern in the modern and aging world; therefore, it necessitates a multisectoral approach that includes families, health care workers, managers, and policy makers.

**Acknowledgments**

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**Data Availability**

The data sets generated and analyzed during this study will be made publicly available, as requested by the funding institution. All requests should be addressed to the corresponding author, as data will be stored on a secured server of the University of Ottawa.

**Authors’ Contributions**

IB conceived the initial idea of the study and is the guarantor of the review. IB, DS, ETN, MPG, SC, JR, APG, and MCL were involved in writing and reviewing the draft of this manuscript. All authors have read and approved the final version of the manuscript.

**Conflicts of Interest**

None declared.

Multimedia Appendix 1

Search strategy:

[DOCX File, 39 KB - aging_v6i1e46753_app1.docx]
Multimedia Appendix 2
Characteristics of included studies.
[DOCX File, 36 KB - aging_v61e46753_app2.docx ]

Multimedia Appendix 3
List of excluded studies and reasons.
[DOCX File, 23 KB - aging_v61e46753_app3.docx ]

Multimedia Appendix 4
Critical appraisal of quality—Specialist Unit for Review Evidence (SURE) checklist.
[DOCX File, 17 KB - aging_v61e46753_app4.docx ]

References
11. Turcotte M, Sawaya C. Senior Care: Differences by Type of Housing Catalogue No. 75-006-X. Ottawa, ON: Statistics Canada; 2015.


32. Have a laugh for loneliness with ALONE this Christmas. ALONE. URL: https://alone.ie/ha-a-laugh-for-loneliness-with-alone-this-christmas/ [Medline: 31992217]

33. Beogo I. Social capitalization through information and communication technologies to reduce social isolation and loneliness. JMIR AGING 2023 | vol. 6 | e46753 | p.103 https://aging.jmir.org/2023/1/e46753


Abbreviations

FC: family caregiver
ICT: information and communication technology
LTC: long-term care
LTCF: long-term care facility
PI: principal investigator
PICO: Population, Interventions, Comparators and designs, Outcomes
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QOL: quality of life
SIL: social isolation and loneliness
SURE: Specialist Unit for Review Evidence
The Nursing Home Severity Index and Application to Pressure Injury Risk: Measure Development and Validation Study

Tracey L Yap¹, PhD, RN, CNE, WCC; Susan D Horn², PhD; Phoebe D Sharkey³, PhD; Katie R Brooks¹, DNP, AGPCNP; Susan Kennerly⁴, PhD, RN, CNE, WCC

¹School of Nursing, Duke University, Durham, NC, United States
²School of Medicine, University of Utah, Salt Lake City, UT, United States
³Selltzer School of Business, Loyola University Maryland, Baltimore, MD, United States
⁴College of Nursing, East Carolina University, Greenville, NC, United States

Corresponding Author:
Tracey L Yap, PhD, RN, CNE, WCC
School of Nursing
Duke University
311 Trent Drive
DUMC 3322
Durham, NC, 27710
United States
Phone: 1 (919) 613 6170
Email: tracey.yap@duke.edu

Abstract

Background: An assessment tool is needed to measure the clinical severity of nursing home residents to improve the prediction of outcomes and provide guidance in treatment planning.

Objective: This study aims to describe the development of the Nursing Home Severity Index, a clinical severity measure targeted for nursing home residents with the potential to be individually tailored to different outcomes, such as pressure injury.

Methods: A retrospective nonexperimental design was used to develop and validate the Nursing Home Severity Index using secondary data from 9 nursing homes participating in the 12-month preintervention period of the Turn Everyone and Move for Ulcer Prevention (TEAM-UP) pragmatic clinical trial. Expert opinion and clinical literature were used to identify indicators, which were grouped into severity dimensions. Index performance and validation to predict risk of pressure injury were accomplished using secondary data from nursing home electronic health records, Minimum Data Sets, and Risk Management Systems. Logistic regression models including a resident’s Worst-Braden score with/without severity dimensions generated propensity scores. Goodness of fit for overall models was assessed using C statistic; the significance of improvement of fit after adding severity components to the model was determined using the likelihood ratio chi-square test. The significance of each component was assessed with odds ratios. Validation based on randomly selected 65% training and 35% validation data sets was used to confirm the reliability of the severity measure. Finally, the discriminating ability of models was evaluated using propensity stratification to evaluate which model best discriminated between residents with/without pressure injury.

Results: Data from 1015 residents without pressure injuries on admission were used for the Nursing Home Severity Index–Pressure Injury and included laboratory, weights/vitals/pain, underweight, and locomotion severity dimensions. Logistic regression C statistic measuring predictive accuracy increased by 19.3% (from 0.627 to 0.748; \(P<.001\)) when adding four severity dimensions to Worst-Braden scores. Significantly higher odds of developing pressure injuries were associated with increasing dimension scores. The use of the three highest propensity deciles predicting the greatest risk of pressure injury improved predictive accuracy by detecting 21 more residents who developed pressure injury (n=58, 65.2% vs n=37, 42.0%) when both severity dimensions and Worst-Braden score were included in prediction modeling.

Conclusions: The clinical Nursing Home Severity Index–Pressure Injury was successfully developed and tested using the outcome of pressure injury. Overall predictive capacity was enhanced when using severity dimensions in combination with Worst-Braden scores. This index has the potential to significantly impact the quality of care decisions aimed at improving individual pressure injury prevention plans.

Trial Registration: ClinicalTrials.gov NCT02996331; http://clinicaltrials.gov/ct2/show/NCT02996331

https://aging.jmir.org/2023/1/e43130
geriatrics; nursing homes; pressure ulcer; propensity scores; severity of illness index; development; validation; clinical; treatment; pressure injury; injury; risk; prevention

Introduction

The aging of the population has resulted in over 1.3 million residents living in nursing home facilities in the United States [1]. Improving the quality of care and containing overall costs will require substantial research efforts to find solutions for how to provide optimal levels of care to these residents. More specifically, an area requiring quality of care improvement for this nursing home population is understanding how to prevent pressure injuries (PIs), given our inability to control the associated pain, infection, and the potential for death once the injury develops. Current prevention approaches have not been as effective as needed; in fact, just being a nursing home resident increases one’s risk of developing a PrI [2]. Nursing home prevention care is guided by the international PrI prevention guidelines [3] that advocate for risk assessment. The Braden Scale for Predicting Pressure Sore Risk (hereafter Braden score) [4] is a commonly used assessment tool to quantify PrI risk represented by a total score and risk categories (low, mild, moderate, high). Many practitioners focus their prevention efforts on residents considered at moderate or high risk. However, PrI incidence remains high among all residents regardless of the Braden score–assessed risk category [5]. The high prevalence of residents who are severely ill makes determining overall PrI risk challenging. Resident attributes beyond the Braden score may add insights to help discriminate those who are at risk of a PrI developing.

Clinical severity, the extent of physiologic decompensation, reflects the overall complexity of a resident’s health status. The severity of illness measures initially were developed in the 1980s using supervised techniques that predict a specific target value, applying statistical methods with historical data. These measures helped to explain why patient mortality, cost, or length of stay differed among hospitals. Their ability to accurately predict a variety of outcomes, however, was limited given that patient attributes were in part defined by specified treatments and created using regression analyses to predict one outcome [6-9].

The Comprehensive Severity Index (CSI) [10,11], which was also developed in the mid-1980s for the evaluation of overall clinical severity levels, applied a substantively different unsupervised method based on judgments of disease-specific medical experts, literature, and clinical textbooks rather than statistical methods, specific outcomes, and use of historical data. This objective measure of clinical severity used physiological, functional, and psychosocial data, including demographics and over 2200 diagnosis-specific signs, symptoms, and physical findings (no treatments). The methodology and CSI are well established and have been validated extensively for over 30 years in patients with many different clinical conditions [10-18].

The development of a clinical severity measure targeted for nursing home residents requires the construction of a new measure with the potential to be individually tailored to different outcomes, such as a PrI. The CSI and other existing clinical severity measures are not appropriate for use with nursing home residents who have large variations in their length of stay, the time windows for data collection, and documentation frequency. This paper reports on the creation of a new clinical severity measure, Nursing Home Severity Index (NHSI), tailored for PrI risk prediction for nursing home residents, and validation using propensity modeling to predict PrI development and explore the measure’s predictive accuracy beyond the Braden score.

Methods

Overview

Development of the NHSI and the selected attributes associated with PrI risk (NHSI-PrI) required initial variable selection, scoring, validation, and propensity modeling to account for independent and confounding variables that affect PrI development and exploration of the measure’s predictive accuracy and validity. A retrospective nonexperimental design was used to examine a broad range of resident attributes to develop the NHSI-PrI. Current study data were based on a 12-month longitudinal data set from each study nursing home to account for seasonal differences.

Study Setting and Population Sample

Residents from 9 skilled nursing homes participating in a 12-month preintervention period (hereafter study period) of the Turn Everyone And Move for Ulcer Prevention (TEAM-UP) embedded pragmatic cluster randomized trial (R01NR016001; ClinicalTrials.gov NCT02996331) [5,19] were involved in this aspect of the study. All 9 participating Medicare and Medicaid–certified skilled nursing homes with ≥100 operating beds were in the same long-term care company and used the same electronic health record (EHR) systems with comprehensive resident clinical information. The population sample included all nursing home residents aged ≥18 years without an existing PrI on study period entry and without regard to diagnoses or demographic attributes.

Ethics Approval

Duke University Institutional Review Board (Duke IRB-Pro00069413) approved the parent project with a waiver of informed consent for nursing home residents.

Development of the Nursing Home Severity Index—Pressure Injury

The NHSI-PrI is a measure of clinical severity for nursing home residents focused on the outcome of PrI risk and development. The first step in creating the NHSI-PrI was selecting the resident attributes to include those that are relevant to a nursing home population. The NHSI-PrI differs from prior clinical severity
measures for acute, ambulatory, or rehabilitation care as it needs to account for greater variability in the length of time residents live in nursing homes and lower frequency of assessments, laboratory, and radiological tests. Skilled care in nursing homes often involves extended stays and uses different frequencies of diagnostics and treatments (including palliative care) from those of other care environments. Acute illness is less common, so laboratory tests are drawn infrequently and often only when there is an acute event. Assessments are made periodically such as at initial admission, quarterly, annually, and on condition change. Residents may need short- or long-term skilled care while recovering from an illness or surgery. Skilled care is characterized by wound and postsurgical care; injected medications; intravenous therapy; physical, occupational, and speech therapy; and regular monitoring of vital signs or disease-specific parameters such as blood glucose levels. Thus, a refined approach to severity measurement was needed to develop a meaningful profile of nursing home residents’ clinical severity.

International Classification of Diseases, Ninth Revision (ICD-9) and International Statistical Classification of Diseases, Tenth Revision (ICD-10) diagnosis codes used for residents within the study period were extracted and similar diagnoses combined (eg, codes for various types of pneumonia were aggregated into one severity criteria set including ICD-9 codes 055.1, 112.4, 136.3, 306.1, 480-486, 506.3, 507-507.1, 516.8, 517-517.1, 518.3, 668-668.04, 997.3, and 998.81, and ICD-10 codes J09.0-J18.9). For each diagnosis aggregate, a comprehensive set of relevant clinical severity indicators of resident attributes was derived from a combination of CSI criteria sets and other sources including Minimum Data Set (MDS) elements, nursing point of care documentation, and Risk Management System data elements: demographics (age, gender, race, and ethnicity) and clinical attributes (eg, laboratory test values; BMI categories, calculated as weight in kgs divided by height in m2: \(<18.5, 18.5-25.0, 25.1-30.0, 30.1-40.0, >40.0\); weights/vital signs/pain data; and additional severity indicators of continence, dementia, locomotion, and dehydration). The inclusion of several of the NHSI severity indicators derived from the federally mandated assessment documentation for Medicare and Medicaid–certified long-term care facilities (MDS) used standardized clinical measures of functional capabilities and health needs specific to nursing home residents.

The second step in the NHSI-PrI development examined the associations and correlations of the severity indicators. Multiple indicators considered as alternative ways to describe the same resident attribute were combined into a single equivalence set (eg, highest or lowest pulse rate, electrocardiogram rhythm, and highest or lowest systolic and diastolic blood pressure to describe cardiovascular abnormality).

The third step developed algorithms to score the NHSI-PrI. A matrix was created to establish up to 4 severity levels for each indicator, their metrics, and the range of metric values applicable for nursing home residents: level 1 (normal to mildly abnormal), level 2 (moderate, nonsustained derangements that are not worrisome), level 3 (severe and worrisome derangements), and level 4 (most severe, catastrophic, life-threatening, or likely to result in organ failure). Equivalence sets were scored only once using the most abnormal indicator level during a specified time window to eliminate double scoring. Also, the most severe score of one or more indicator observations during a specified time window was used only once (eg, most abnormal body temperature recorded on different dates). The choice of severity levels was based on unsupervised methods using expert clinical judgment, literature, and clinical textbooks [10]. An expert panel of nurses and physicians on our research team reviewed the selected indicators and the associated 4 levels of severity thresholds necessary to create a measure of severity appropriate for nursing home residents. Based on previous literature and expert panel opinion, indicators were grouped into dimensions, laboratory, weights/vitals/pain, locomotion, and underweight. Next, expert panel reviewers interpreted the four indicator severity level scores as nonlinear and applied an exponential weighting function using a complex heuristic to create continuous NHSI-PrI dimension scores.

The final step in NHSI-PrI development involved validity testing. Secondary data from nursing home EHR, MDS, and Risk Management System data were used to validate the NHSI-PrI. The most commonly used measure in the United States to predict PrI risk, the Braden score [20], was examined in predictive models with and without severity dimensions. The Braden score is comprised of six subscales (sensory perception, mobility, activity, moisture, nutrition, and friction and shear) that are summed in a rating scale to help clinicians identify those at-risk for PrI development and to guide preventive measures based on risk factors. The subscales are rated from 1 to 4 (except friction and shear rated from 1 to 3), with 6-23 total points possible. Predictive validity varies by setting [21,22]. Risk categories for PrIs are based on total Braden scores: low (19-23), mild (15-18), moderate (13-14), and high (10-12) PrI risk.

A unique feature of the NHSI-PrI development used automatic severity scoring based on EHR, MDS, and Risk Management System data avoiding manual time-consuming abstraction. A computer algorithm was designed to generate the 4 severity levels according to extent of abnormality: the more abnormal the resident attributes, the higher the severity indicator levels and the NHSI-PrI’s severity dimension scores.

**Data and Data Management**

Categories of EHR data used were vital signs, MDS elements, laboratory test values, and nursing point-of-care activities of daily living documentation. Data were extracted directly from EHRs with computer algorithms (code) created with SAS version 9.4 (SAS Institute Inc) [23]. All electronic data downloads were performed by the nursing home company in a Health Insurance Portability and Accountability Act–compliant format with the creation of a study identification number for each resident prior to data downloading and being transferred to Duke University’s secure drive space designated for the TEAM-UP study.

**Issues Defining Time Window of Exposure and Clinical Severity Measurements**

Nursing homes conduct laboratory tests and other assessments infrequently, and enough time is needed to have sufficient data
when resident clinical severity is most likely related to the outcome of interest. Also, residents’ severity measure comparisons depend on the standardization of an exposure window for the amount of time a person is observed and at risk for the outcome of interest. An exposure time window should reflect the period during which its effects are relevant to the specified outcome. Important factors to consider when defining exposure are the length of time, changes in exposure status, and consistency and accuracy of exposure measurements. Frequency, format, and intensity of residents’ observations are other important considerations. Clinical judgment was used to establish a 92-day window prior to the first PrI, which was a similar period to the typical quarterly Braden score and other resident assessments. For residents who did not develop PrIs, severity scores were based on indicator values during the final 92 days before discharge (death, transfer) from the nursing home or the end of the study period since residents are often sickest when they are older.

**Statistical Analysis**

Descriptive statistics (means, SDs, frequencies, percentages) were used to describe demographic and clinical resident attributes with/without PrIs and were compared using 2-tailed t tests or chi-square tests as appropriate. A resident’s most severe Braden score (Worst-Braden) occurring during the 92 days prior to PrI development, discharge/death, or end of the study period was used to define risk categories of low (19-23), mild (15-18), moderate (13-14), and high (10-12). Validation methods included correlations overall and by Worst-Braden risk category followed by logistic regression models with/without severity dimensions to generate propensity scores or probabilistic estimates that a resident develops a PrI. Predictors (independent variables) included NHSI-PrI dimension scores and Worst-Braden score. The goal of these analyses was to assess the predictive capacity of three models: model 1 based on Worst-Braden scores alone, model 2 based on four NHSI-PrI dimensions, and model 3 based on Worst-Braden scores plus four severity dimensions.

Goodness of fit for logistic regression models was assessed in several ways. First, the overall models (relationship between the independent variables and the dependent variable) were assessed using a C statistic with a minimum value of 0.50 corresponding to chance and a maximum value of 1.0 (perfect prediction). To test the significance of improvement in fit after adding severity dimensions to the model, differences in C statistics between models with/without severity were examined using a likelihood ratio chi-square test. Second, the significance of each severity dimension was assessed by examining odds ratios (ORs) to determine the relative amount by which the odds of the dependent variable increased (OR≥2.0) or decreased (OR<1.0) when the value of the corresponding dimension variable increased by 1 unit. Third, the predictive accuracy or discriminating ability of the models was evaluated using propensity stratification. Observations were divided into equally sized strata defined by deciles of their sorted propensity scores to examine which model best discriminated between residents with/without PrIs. As a final validation of the NHSI-PrI, the study sample was randomly divided into a 65% training data set and a 35% validation data set, and the same validation statistics specified above were computed for each data set.

**Results**

There were 1015 residents in 9 nursing homes during the study period who met the study inclusion criteria and had comprehensive EHR data in the relevant 92-day window for risk of PrI development. Across all 9 nursing homes, between 2.3% (n=3) to 18.3% (n=31) of residents developed PrIs for a total of 8.8% (n=89) having PrIs during the study period.

Table 1 compares attributes of residents with/without PrIs. There were no significant differences in age, gender, or race/ethnicity. However, the length of stay during the study period was significantly longer, although only 16 days, or 4.9%, for residents who developed PrIs versus those who did not. Significantly fewer residents with BMI ≥30 (n=21, 6.6%) and significantly more residents with BMI <18.5 (n=15, 18.5%) developed PrIs. Residents who developed a PrI had significantly lower (more severe) Worst-Braden scores and a greater percentage of residents in higher risk categories. All 4 of the NHSI-PrI severity dimensions (laboratory, weights/vitals/pain, locomotion, and underweight) indicated significantly greater clinical severity during the 92-day period before residents developed a PrI compared to the 92-day period prior to discharge for residents who did not develop PrIs.

Textbox 1 describes examples of clinical severity indicators contained in each of the 4 NHSI-PrI dimensions. The most abnormal values for these indicators during the 92-day window were used to quantify the severity of each indicator.

Different severity dimensions were associated with PrI development in residents classified by each of the Worst-Braden risk categories (Table 2). The higher the severity dimension score the more likely a PrI was to develop. The locomotion and underweight dimensions were significantly associated with PrI development for residents in low- and mild-risk categories, while the laboratory and weights/vitals/pain dimensions were significantly associated with PrI development for residents in moderate- and high-risk categories.

The C statistics from three logistic regression models captured the magnitude of improvement associated with adding severity dimensions to predictive models starting with the Worst-Braden score alone (Table 3). Age, gender, and race/ethnicity were not significant in predicting PrIs. The Worst-Braden score alone (model 1) provided limited predictive accuracy (C=0.627); the C statistic was 0.725 or 15.6% better using all four NHSI-PrI severity dimensions (model 2); C increased a little further to 0.748 or 19.3% better when the Worst-Braden score was added to the four NHSI-PrI dimensions (model 3), which improved the goodness of fit (model 1 vs model 3) significantly (P<.001).

The magnitude of this improvement is best gauged by examining the ORs of the individual severity dimensions. For model 3, an increase of 5 points in the locomotion dimension score increases the likelihood of PrI by 75%. A 5-point increase in the underweight dimension score increases the likelihood of PrI by 50%.
Table 1. Comparison of characteristics for residents without and with pressure injuries (PrIs) during the preintervention time period (N=1015).

<table>
<thead>
<tr>
<th>Demographic and clinical characteristics</th>
<th>Total population (N=1015)</th>
<th>Residents without PrI (n=926)</th>
<th>Residents with PrI (n=89)</th>
<th>T test, F test, or chi-square (df)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resident age (years), mean (SD)</td>
<td>77.94 (12.9)</td>
<td>77.85 (12.9)</td>
<td>78.87 (12.5)</td>
<td>-0.71 (1013)</td>
<td>.48</td>
</tr>
<tr>
<td>Male, n (%)</td>
<td>357 (35.17)</td>
<td>329 (35.5)</td>
<td>28 (31.5)</td>
<td>0.77 (1013)</td>
<td>.44</td>
</tr>
<tr>
<td>BMI (kg/m^2), n (%)</td>
<td></td>
<td></td>
<td></td>
<td>18.33 (3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&lt;18.5</td>
<td>81 (8.0)</td>
<td>66 (7.1)</td>
<td>15 (16.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.5 to &lt;25</td>
<td>383 (37.7)</td>
<td>341 (36.8)</td>
<td>42 (47.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.0 to &lt;30</td>
<td>233 (23.0)</td>
<td>222 (24.0)</td>
<td>11 (12.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;30</td>
<td>318 (31.3)</td>
<td>297 (32.1)</td>
<td>21 (23.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race/ethnicity, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>1.36 (2)</td>
<td>.51</td>
</tr>
<tr>
<td>Asian</td>
<td>32 (3.2)</td>
<td>29 (3.1)</td>
<td>3 (3.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>333 (32.8)</td>
<td>299 (32.3)</td>
<td>34 (38.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>650 (64.0)</td>
<td>598 (64.6)</td>
<td>52 (58.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braden-First score^a, mean (SD)</td>
<td>18.00 (2.9)</td>
<td>18.13 (2.9)</td>
<td>16.66 (2.7)</td>
<td>4.57 (108.80)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Braden-MEAN score^b, mean (SD)</td>
<td>17.61 (2.7)</td>
<td>17.78 (2.7)</td>
<td>15.84 (2.2)</td>
<td>7.75 (115.41)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Braden-Worst score^c, mean (SD)</td>
<td>16.43 (3.3)</td>
<td>16.55 (3.3)</td>
<td>15.19 (2.7)</td>
<td>4.42 (115.11)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Braden-MEAN risk categories based on Braden-MEAN scores^b, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>20.95 (3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Low risk (score 19-23)</td>
<td>469 (46.2)</td>
<td>448 (48.4)</td>
<td>21 (23.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild risk (score 15-18)</td>
<td>434 (42.8)</td>
<td>382 (41.3)</td>
<td>52 (58.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate risk (score 13-14)</td>
<td>82 (8.1)</td>
<td>71 (7.7)</td>
<td>11 (12.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High risk (score 10-12)</td>
<td>30 (3.0)</td>
<td>25 (2.7)</td>
<td>5 (5.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Braden-Worst risk categories based on Braden-Worst scores^c, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>12.17 (3)</td>
<td>.007</td>
</tr>
<tr>
<td>Low risk (score 19-23)</td>
<td>282 (27.8)</td>
<td>270 (29.2)</td>
<td>12 (13.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild risk (score 15-18)</td>
<td>442 (43.6)</td>
<td>401 (43.3)</td>
<td>41 (46.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate risk (score 13-14)</td>
<td>171 (16.9)</td>
<td>149 (16.1)</td>
<td>22 (24.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High risk (score 10-12)</td>
<td>120 (11.8)</td>
<td>106 (11.5)</td>
<td>14 (15.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weights/vitals/pain severity dimension score, mean (SD)</td>
<td>14.70 (12.2)</td>
<td>14.37 (12.2)</td>
<td>18.16 (11.8)</td>
<td>-2.81 (1013)</td>
<td>.005</td>
</tr>
<tr>
<td>Locomotion (On_Off) severity dimension score, mean (SD)</td>
<td>2.34 (3.1)</td>
<td>2.20 (3.0)</td>
<td>3.83 (3.7)</td>
<td>-4.08 (99.37)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Laboratory severity dimension score, mean (SD)</td>
<td>6.22 (11.1)</td>
<td>5.71 (10.5)</td>
<td>11.54 (15.1)</td>
<td>-3.56 (96.44)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Length of stay-total^d (days), mean (SD)</td>
<td>1349 (1287)</td>
<td>1326 (1287)</td>
<td>1591 (1270)</td>
<td>-1.86 (106.15)</td>
<td>.06</td>
</tr>
<tr>
<td>Length of stay during preintervention study period^e (days), mean (SD)</td>
<td>327 (821)</td>
<td>326 (83)</td>
<td>342 (66)</td>
<td>-2.11 (116.37)</td>
<td>.04</td>
</tr>
</tbody>
</table>

^aBraden-First score: first Braden score occurring during the preintervention period.

^bBraden-MEAN score: mean of all Braden scores occurring during the preintervention period.

^cBraden-Worst score: worst Braden score occurring during the 92 days prior to pressure injury development, discharge/death, or end of the preintervention period.

^dLength of stay total: number of days from nursing home admission to end of preintervention period, mean (SD).

^eLength of stay preintervention study period: number of days during preintervention time period, mean (SD).
**Textbox 1.** Description of the Nursing Home Severity Index-Pressure Injury (NHSI-PrI) clinical severity dimensions and their indicators. Weights for each indicator comprising a dimension are summed to produce a dimension score.

### Laboratory dimension
- Lowest platelets \((10^3/\mu L)\), lowest female hemoglobin (HGB; g/dl), lowest female hematocrit (HCT; %), lowest male HGB (g/dl), lowest male HCT (%)
- Highest glucose (mg/dl), highest hemoglobin \(A_1C\) (n x norm)
- Highest/lowest potassium (K; mEq/L)
- Highest blood urea nitrogen (mg/dl), highest creatinine (mg/dl), lowest albumin (mg/dl)
- Highest aspartate transaminase (serum glutamic-oxaloacetic transaminase; n x norm), highest alanine transaminase (serum glutamic-pyruvic transaminase; n x norm)
- Highest sodium (NA; mEq/L), lowest sodium (mEq/L)
- Highest 24 hr urine protein (mg/dl), highest urine protein via dipstick
- \(O_2\) saturation on pulse oximetry (%), arterial blood gases, lowest pH (no units), lowest \(pO_2\) (mm/Hg), highest pH (no units), lowest total venous \(CO_2\) (mEq/L)
- Highest white blood cell count (WBC; k/cu mm), highest bands (%), lowest WBC (k/cu mm)
- Lowest lymphocytes (%)
- Highest total bilirubin (mg/dl)
- Highest total calcium (mg/dl)
- Highest alkaline phosphatase (u/l)

### Underweight dimension
- BMI <18.5 kg/m\(^2\)

### Weights, vitals, pain dimension
- Infiltrates/consolidation in lungs, rales/rhonchi/wheezes, dyspnea, breath sounds, kussmaul breathing, sputum/secretions
- Highest temperature, rigors/chills, lowest temperature
- Highest pulse rate, electrocardiogram rhythm, highest blood pressure systolic, highest blood pressure diastolic, lowest pulse rate, lowest systolic blood pressure, orthostatic blood pressure
- Weight loss, cachexia, weight gain, general pain
- Pulse characteristics
- Chest pain

### Locomotion dimension (locomotion dimension indicators are calculated as average/day frequency)
- Locomotion OFF unit with wheelchair
- Locomotion OFF unit with wheeled recliner
- Locomotion OFF unit one person assist
- Locomotion OFF unit total dependence
- Locomotion ON unit one person assist
- Locomotion ON unit total dependence
Table 2. Correlations among predictor variables and outcome of pressure injury used in logistic regression models.

<table>
<thead>
<tr>
<th>Predictor variable</th>
<th>Total residents (N=1015; PrI n=89)</th>
<th>Pressure injury low risk (n=282; PrI n=12)</th>
<th>Pressure injury mild risk (n=442; PrI n=41)</th>
<th>Pressure injury moderate risk (n=171; PrI n=22)</th>
<th>Pressure injury high risk (n=120; PrI n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worst-Braden</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-0.12</td>
<td>-0.09</td>
<td>-0.12</td>
<td>0.02</td>
<td>0.13</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.001</td>
<td>.12</td>
<td>.01</td>
<td>.79</td>
<td>.17</td>
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<tr>
<td>Laboratory dimension</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>r</td>
<td>0.15</td>
<td>0.07</td>
<td>0.12</td>
<td>0.22</td>
<td>0.29</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.001</td>
<td>.22</td>
<td>.01</td>
<td>.003</td>
<td>.001</td>
</tr>
<tr>
<td>Weights/vitals/pain dimension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.09</td>
<td>0.28</td>
<td>0.09</td>
<td>0.09</td>
<td>0.19</td>
</tr>
<tr>
<td>P value</td>
<td>.004</td>
<td>.64</td>
<td>.05</td>
<td>.23</td>
<td>.04</td>
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<tr>
<td>Locomotion dimension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.15</td>
<td>0.21</td>
<td>0.15</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>P value</td>
<td>&lt;.001</td>
<td>&lt;.001</td>
<td>.002</td>
<td>.23</td>
<td>.26</td>
</tr>
<tr>
<td>Underweight dimension</td>
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<td></td>
</tr>
<tr>
<td>r</td>
<td>0.10</td>
<td>0.17</td>
<td>0.11</td>
<td>0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>P value</td>
<td>.001</td>
<td>.005</td>
<td>.02</td>
<td>.32</td>
<td>.83</td>
</tr>
</tbody>
</table>

\(^a\)PrI: pressure injury.

Table 3. Logistic regression models predicting pressure injury development.

<table>
<thead>
<tr>
<th>Logistic regression model</th>
<th>Estimates</th>
<th>Standard error</th>
<th>P value</th>
<th>Odds ratio (95% CI)</th>
<th>C statistic (df)</th>
<th>Likelihood ratio chi-square test</th>
<th>Chi-square (df)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1 (Braden)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worst-Braden score</td>
<td>-0.12</td>
<td>0.035</td>
<td>&lt;.001</td>
<td>0.88 (0.82-0.94)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 2 (NHSI-PrI(^b))</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight dimension</td>
<td>0.098</td>
<td>0.036</td>
<td>.006</td>
<td>1.10 (1.03-1.18)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Laboratory dimension</td>
<td>0.030</td>
<td>0.008</td>
<td>&lt;.001</td>
<td>1.03 (1.01-1.05)</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Weights/vitals/pain dimension</td>
<td>0.024</td>
<td>0.009</td>
<td>.009</td>
<td>1.02 (1.01-1.04)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Locomotion dimension</td>
<td>0.149</td>
<td>0.034</td>
<td>&lt;.001</td>
<td>1.16 (1.09-1.24)</td>
<td></td>
<td></td>
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<tr>
<td>Model 3 (Braden + NHSI-PrI)</td>
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<tr>
<td>Worst-Braden score</td>
<td>-0.121</td>
<td>0.037</td>
<td>.001</td>
<td>0.89 (0.82-0.95)</td>
<td></td>
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<tr>
<td>Underweight dimension</td>
<td>0.097</td>
<td>0.360</td>
<td>.007</td>
<td>1.10 (1.03-1.18)</td>
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<tr>
<td>Laboratory dimension</td>
<td>0.031</td>
<td>0.008</td>
<td>&lt;.001</td>
<td>1.03 (1.02-1.05)</td>
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<tr>
<td>Weights/vitals/pain dimension</td>
<td>0.025</td>
<td>0.009</td>
<td>.007</td>
<td>1.03 (1.01-1.04)</td>
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<tr>
<td>Locomotion dimension</td>
<td>0.140</td>
<td>0.034</td>
<td>&lt;.001</td>
<td>1.15 (1.08-1.23)</td>
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\(^a\)N/A: not applicable.  
\(^b\)NHSI-PrI: Nursing Home Severity Index–Pressure Injury.  
\(^c\)Comparing goodness of fit of two models: model 2 versus model 1.  
\(^d\)Comparing goodness of fit of two models: model 3 versus model 1.

The histogram in Figure 1 summarizes the propensity score results generated from prediction models using model 1 (only Worst-Braden score) versus model 2 (only 4 NHSI-PrI dimensions) or model 3 (Worst-Braden score plus 4 NHSI-PrI dimensions). The top decile for each model contains 10% of the population most likely to develop a PrI and the bottom decile contains 10% of the population with the lowest likelihood of PrI. The deciles and number of study residents who actually...
developed PrIs in that decile are graphed on the x and y axes, respectively. Models 2 and 3 exhibit patterns of mostly “staircase” increases for each decile demonstrating that the models “binned” the residents correctly from those least likely to develop a PrI to most likely. In contrast, model 1 exhibits an irregular pattern for each decile, both up and down, indicating that the model is not doing as good a job of predicting a resident’s likelihood for PrI. More than 65% (n=58) of residents with PrIs are identified in the three highest propensity deciles using models 2 and 3 compared to only about 42% (n=37) of residents with PrIs in the three highest deciles using model 1. Thus, using propensity score analysis, the inclusion of severity dimensions in models 2 and 3 resulted in the identification of 21 more residents at greater risk (in the three highest propensity deciles) of developing a PrI than in model 1.

The outcome of PrI development was also used to validate the NHSI-PrI results for training and validation data sets. The randomly selected training data set contained 56 PrIs in 658 residents, and the validation data set contained 33 PrIs in 357 residents. For training data, the corresponding predicted C statistics were 0.618 (model 1), 0.717 (model 2), and 0.735 (model 3), resulting in an 18.9% improvement from model 1 to 3. For validation data, the C statistics were 0.648 (model 1), 0.810 (model 2), and 0.816 (model 3), resulting in a 25.9% improvement from model 1 to 3.

Figure 1. Propensity deciles for all models. PrI: pressure injuries.

Discussion

Principal Findings

Multiple different approaches were used to validate the NHSI-PrI to predict residents at risk for PrI development. Model statistics improved from using the Worst-Braden score alone (C=0.627) to using NHSI-PrI alone (C=0.725) to combining the Worst-Braden score and NHSI-PrI (C=0.748). Looking at propensity score deciles versus actual results also validated the improvement indicated by NHSI-PrI. Finally, randomly dividing the data into training and validation data sets showed that the training values had similar corresponding C statistics for Worst-Braden scores alone versus NHSI-PrI alone versus the combination of the two.

Measuring resident clinical severity and predicting a specific outcome such as PrI involves an examination of numerous resident attributes (eg, physiologic, functional, and psychosocial variables during a specified window of time) and potentially hundreds of data points. Using existing and relevant data, nursing home outcomes can only be evaluated accurately when pertinent resident attributes that impact the resulting outcomes are included. There is no way to demonstrate whether differences in outcomes are associated with either health interventions, differences in clinical severity, or both if critical aspects of a resident’s clinical severity are not included. Clinical severity in nursing home residents is challenging to define given the multitude of factors affecting the overall health status of older adults who are potentially further compromised by residing in a nursing home [2]. Significant differences are evident in clinical severity definitions for adults in differing care settings. For example, a severity indicator label may be the same for an adult cared for in acute care or a nursing home setting, but nursing home resident outcome prediction required modification in that indicator’s thresholds due to substantial differences in age-related attributes. Identification of new severity indicators and new thresholds for some of those indicators were needed when applied to older adult residents.

Multiple different data sources with varied recording formats and coding patterns for the same indicator were encountered in developing and programming the new NHSI-PrI measure, making synchronization of data elements challenging. Yet, it was required to avoid subsequent issues interpreting analysis results.

Strengths

The new NHSI-PrI measure has two unique features: (1) capacity for automatic scoring and (2) daily calculation. First, the NHSI-PrI was designed by clinical experts to be scored automatically from downloaded structured EHR data including vital signs, MDS data elements, laboratory test values, weights, etc. Second, the NHSI-PrI measure can be calculated daily based on findings during the most recent prior 92-day time window,
allowing for evolving clinical severity changes to be monitored over time.

There is a substantial benefit to identifying and monitoring known PrI predictors and improving prediction using electronic data in addition to the existing Braden score. Little is known about differences in who does and does not develop a PrI, especially among nursing home residents. PrI prevention efforts are well established according to international guidelines, yet PrI incidence has remained high in nursing homes. Historically, clinically assessed PrI risk among residents has resulted in most preventive resources being allocated to residents evaluated at moderate or high risk. However, significant numbers of PrIs also occur in residents in low and mild Worst-Braden risk categories [5]. This research supports the value of a well-discriminating model that differentiates residents with a higher likelihood of developing a PrI from those with a lower likelihood. These findings suggest that relying on the Worst-Braden score alone is a weak predictor. The use of the Worst-Braden score in combination with four severity dimensions of the NHSI-PrI significantly enhances the accuracy of PrI prediction. This new knowledge can be used to design and modify resident-specific PrI prevention plans. Thus, the addition of specific NHSI-PrI dimensions to current risk assessment resources has the potential to substantially impact quality care decisions aimed at improving PrI prevention outcomes, especially among different Worst-Braden risk categories.

Limitations
This study had several limitations that may affect the reproducibility and generalizability of results. First, nursing home populations have several unique characteristics that provide challenges for identifying comparable discrete times of exposure or defined time frames. For example, it was assumed that residents’ exposure time had a clearly defined start and end date when in fact this varied across residents. An up to 92-day window was determined to be most clinically relevant and applied to define exposure duration to measure and compare clinical severity for residents with and without PrIs. Results may differ if shorter or longer time windows are applied. The approach used in computing the NHSI-PrI directly from downloaded structured electronically available data may have limited the variety of indicators that could be included in the NHSI-PrI and may need updating as more relevant structured electronic data become available.

Second, our models are not directly linked in real time to measures for risk mitigation. This is due to the fact that clinical severity data in nursing homes are captured less frequently than ongoing clinical appraisals in other settings. Some observations that may be useful predictors are recorded only every quarter. This limits the precision of risk indicators that can be used. More frequent measurement of relevant severity clinical indicators would likely improve the predictive ability of NHSI-PrI.

Future Directions
Substantive strides are needed to standardize health care data to facilitate process improvements in data interpretation for future studies. Determination of severity levels required complex data interpretation from various sources for which there is currently no data field standardization. The substantial amount of coding across electronic data formats was a fundamental challenge. Data values needed to be converted to equivalents and interpreted for descriptive data fields to assign severity levels. Data standardization and interpretive processes were carefully performed, checked, and further evaluated taking clinical judgment into account. This process required significant effort to minimize inconsistencies.

Finally, the effectiveness of the NHSI-PrI using a larger sample of nursing home facilities and residents is unclear. Our sample was divided into training and validation data sets, each of which well represented the whole data set to test generalizability. Larger confirmatory studies with a different cohort of nursing home residents and facilities should establish the reliability and validity of the new NHSI-PrI and its results.

Conclusions
The newly created NHSI-PrI was successful in developing a meaningful profile of clinical severity among nursing home residents and accurately predicting the risk of PrI development. Findings support that clinical severity dimension scores can be used in combination with Worst-Braden scores to augment PrI prediction and potentially impact the quality of care decisions aimed at improving individual PrI prevention plans.

Data Availability
The data used in this publication include protected health information and therefore cannot be freely shared. Data sharing will be possible with case-by-case approval from the authors’ institutional review board; requests may be directed to the principal investigator.

Conflicts of Interest
TLY is a JMI Aging editorial board member at the time of this publication and is on the Smith and Nephew speaker bureau. The other authors have no conflicts of interest to declare.

References


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**Abbreviations**

- **CSI**: Comprehensive Severity Index
- **EHR**: electronic health record
- **ICD-9**: International Classification of Diseases, Ninth Revision
- **ICD-10**: International Statistical Classification of Diseases, Tenth Revision
- **MDS**: Minimum Data Set
NHSI: Nursing Home Severity Index
NHSI-PRI: Nursing Home Severity Index–Pressure Injury
OR: odds ratio
PrI: pressure injury
TEAM-UP: Turn Everyone and Move for Ulcer Prevention

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Original Paper

Exploring the Role of Active Assisted Living in the Continuum of Care for Older Adults: Thematic Analysis

Gaya Bin Noon¹, BSc; Thokozani Hanjahanja-Phiri¹, BSocSci, MPhil, PhD; Harishree Dave¹, BSc; Laura Fadrique¹,², MSc; Jennifer Teague³, BSc, MSc, PhD; Plinio P Morita¹,⁴,⁵,⁶,⁷, BEng, MSc, PhD

¹School of Public Health Sciences, University of Waterloo, Waterloo, ON, Canada
²Communitech, Waterloo, ON, Canada
³Canadian Standards Association, Toronto, ON, Canada
⁴Research Institute for Aging, University of Waterloo, Waterloo, ON, Canada
⁵Department of Systems Design Engineering, University of Waterloo, Waterloo, ON, Canada
⁶Centre for Digital Therapeutics, Techna Institute, University Health Network, Toronto, ON, Canada
⁷Institute of Health Policy, Management, and Evaluation, Dalla Lana School of Public Health, University of Toronto, Toronto, ON, Canada

Corresponding Author:
Plinio P Morita, BEng, MSc, PhD
School of Public Health Sciences
University of Waterloo
TJB-2266
200 University Ave W
Waterloo, ON, N2L 3G1
Canada
Phone: 1 519 888 4567 ext 41372
Email: plinio.morita@uwaterloo.ca

Abstract

Background: Active assisted living (AAL) refers to systems designed to improve the quality of life, aid in independence, and create healthier lifestyles for those who need assistance at any stage of their lives. As the population of older adults in Canada grows, there is a pressing need for nonintrusive, continuous, adaptable, and reliable health monitoring tools to support aging in place and reduce health care costs. AAL has great potential to support these efforts with the wide variety of solutions currently available; however, additional work is required to address the concerns of care recipients and their care providers with regard to the integration of AAL into care.

Objective: This study aims to work closely with stakeholders to ensure that the recommendations for system-service integrations for AAL aligned with the needs and capacity of health care and allied health systems. To this end, an exploratory study was conducted to understand the perceptions of, and concerns with, AAL technology use.

Methods: A total of 18 semistructured group interviews were conducted with stakeholders, with each group comprising several participants from the same organization. These participant groups were categorized into care organizations, technology development organizations, technology integration organizations, and potential care recipient or patient advocacy groups. The results of the interviews were coded using a thematic analysis to identify future steps and opportunities regarding AAL.

Results: The participants discussed how the use of AAL systems may lead to improved support for care recipients through more comprehensive monitoring and alerting, greater confidence in aging in place, and increased care recipient empowerment and access to care. However, they also raised concerns regarding the management and monetization of data emerging from AAL systems as well as general accountability and liability. Finally, the participants discussed potential barriers to the use and implementation of AAL systems, especially addressing the question of whether AAL systems are even worth it considering the investment required and encroachment on privacy. Other barriers raised included issues with the institutional decision-making process and equity.

Conclusions: Better definition of roles is needed in terms of who can access the data and who is responsible for acting on the gathered data. It is important for stakeholders to understand the trade-off between using AAL technologies in care settings and the costs of AAL technologies, including the loss of patient privacy and control. Finally, further work is needed to address the gaps, explore the equity in AAL access, and develop a data governance framework for AAL in the continuum of care.
Introduction

Background

Canada has a growing aging population, which has led to a pressing need for nonintrusive, continuous, and reliable health monitoring tools that can support aging in place [1-4] and reduce health care costs [4,5]. One of the biggest challenges in helping older adults continue to age in their own homes and communities is the increasing prevalence of chronic diseases as individuals continue to live longer [6]. Moreover, the COVID-19 pandemic has accelerated the need for remote monitoring tools that enable clinicians to support their patients from a distance with fewer clinic visits and hospital admissions [7,8].

Active assisted living (AAL) technologies can improve the quality of life, aid in independence, and create healthier lifestyles for those who need assistance at any stage of their lives. Three years ago, the demand for services and technologies that support telehealth, AAL, and internet of things (IoT) for health was not met, as many technologies were still in their infancy when the pandemic began [9]. Consequently, the pandemic incentivized the accelerated commercialization of products, and the market was flooded with products of lower quality [9]. This, in turn, increased the need for technology guidelines and an ecosystem capable of accommodating new technologies as they become available [10].

Other concerns arising from the rapid integration of AAL and IoT into care, such as the loss of care recipients’ privacy and control over their own information, have not been adequately addressed [11]. In addition, care recipients may fear the loss of independence owing to actions taken by caregivers and care providers based solely on AAL data or a growing dependence on the technology without making other considerations [2,9].

Goal of This Study

The study was conducted in close collaboration with care providers and other stakeholders to ensure that the recommendations for system-service integrations aligned with the needs and capacity of the health care and allied health systems. This study also recognized that the individual needs of users extend beyond the home environment to include services and data collected at the community and city levels. Therefore, this was an exploratory study with the aim of understanding the opportunities for and challenges of integrating AAL technologies into the health system at the community level (eg, into the practice of paramedicine and other emergency services, pharmacies, allied health professional services, and medical clinics).

Study Rationale

As a core goal of the AAL technology ecosystem is to promote independent living and improve the quality of life for vulnerable individuals, the authors not only considered the user’s home but also addressed the individual AAL requirements beyond the home environment, including services and data collected at the community and city levels. Unfortunately, AAL technologies are rarely integrated with external services, especially community health services [11-13]. The primary use of AAL in the continuum of care is to support integrated care [14], and successful integrated care depends on seamless transitions between care services and settings. Integrated care should also include coordinated care that offers access to services within a reasonable time frame, as well as effective treatment, self-care support, respect for care recipients’ preferences, and appropriate involvement of family members and other informal caregivers [14,15]. Some simple solutions identified in the literature for improving the continuity of AAL include accurate contact information for care providers and discharge information that is clear and tailored to the care recipient [16,17].

Over the years, attempts have been made to integrate IoT and AAL technologies into the homes of older adults; however, there are practical and financial considerations for developing and implementing these integrations [8,13,18]. Besides these considerations, there is a trade-off between health technology use and the right to privacy, but the incentive must be at least greater than the effort of learning how to use the technology and loss of one’s privacy because of sharing data with service providers [19-22]. Specifically, the advantages offered to older adults from adopting a health technology (ie, better support for independent living, reduced dependence on others, or the ability to navigate the physical environment of their home or care setting) must be perceived to be greater than the loss of privacy and perceived loss of control [11,22].

Conceptual Framework

In this conceptual framework for an AAL system, a user is a care recipient who becomes a data participant when their personal data are collected by different technologies. An actor refers to an entity that communicates and interacts in the system, including persons, technical components, software applications, systems, databases, and other bodies that play a role in the system. In an AAL system, an agent refers to any person interacting with the system, excluding the care recipient, or any person interacting with the care recipient along the continuum of care, including traditional health care provider users, allied health professionals, informal caregivers, and paraprofessionals. A visualization of the conceptual framework is presented in Figure 1.
Traditional health care providers are traditional in the sense that, in addition to being naturally associated with the term health care providers, past pilot projects that have sought to integrate data from AAL technologies into care typically first seek to include them. This group includes physicians, nurses, pharmacists, and social workers. Agents playing additional roles associated with the care of older adults, such as transition care coordinators or geriatric care managers, are included here if they perform these roles in the context of their work as a nurse or social worker. Allied health professionals refers to agents who work in the health care context and are paid through public funding but have not commonly been included in past pilot projects of integrated AAL systems. Agents in this group can still benefit from the data obtained from AAL systems (eg, data related to movement, room temperature, and use of tracked or radio-frequency identification–tagged items) if they are properly interpreted and targeted to their work. Allied health professionals refers to agents who work in the health care context and are paid through public funding but have not commonly been included in past pilot projects of integrated AAL systems. Agents in this group can still benefit from the data obtained from AAL systems (eg, data related to movement, room temperature, and use of tracked or radio-frequency identification–tagged items) if they are properly interpreted and targeted to their work. Allied health professionals refers to agents who work in the health care context and are paid through public funding but have not commonly been included in past pilot projects of integrated AAL systems. Agents in this group can still benefit from the data obtained from AAL systems (eg, data related to movement, room temperature, and use of tracked or radio-frequency identification–tagged items) if they are properly interpreted and targeted to their work. Allied health professionals refers to agents who work in the health care context and are paid through public funding but have not commonly been included in past pilot projects of integrated AAL systems. Agents in this group can still benefit from the data obtained from AAL systems (eg, data related to movement, room temperature, and use of tracked or radio-frequency identification–tagged items) if they are properly interpreted and targeted to their work.

Para-professionals are agents who directly impact the quality of life but are unlikely to directly interact with AAL technologies. Examples include agents hired for home maintenance, meal delivery, transportation, or housekeeping or volunteers who provide similar services. Finally, health technologies refers to any technology developed to prevent, diagnose, or treat medical conditions; promote health; provide rehabilitation; or organize health care delivery [23]. In the context of AAL, the goal of health technologies is to facilitate the wellness of and help maintain the independence of older adults.

Methods

Study Design

One round of 18 semistructured, small-group interviews was held with stakeholders involved in the care of older adults or development, manufacturing, or integration of care-related technologies between March and May 2022. This interview method was chosen because of its flexibility in obtaining targeted and unique perspectives of different stakeholders and understanding the interactions between different staff members in the same organization (where applicable) [24]. A semistructured interview guide with 16 questions was developed (Multimedia Appendix 1). An expert in the field of user-centered design and human factors methods provided guidance on the formulations of the questions for the interview.

In the interviews, the agents were asked for details about their experiences with the use of technology in the care of older adults; the interviews were guided by a data governance framework that was intentionally broad (ie, not AAL specific). Participants were recruited from the following four groups:

Figure 1. Existing landscape of active assisted living (AAL) technologies and their applications in the continuum of care.
1. Care organizations: stakeholders working for organizations directly involved in care delivery (e.g., retirement communities, long-term care homes, and community care organizations)
2. Technology developers: stakeholders working for companies or groups involved in the development or manufacturing of AAL technologies
3. Technology integrators: stakeholders working for companies or groups involved in the integration of AAL technologies into care
4. Reception: potential care recipients and patient advocates representing the interests of older adults

In total, >40 stakeholders from Canada and the United States were invited to participate in the interviews. Some of the stakeholders contacted also forwarded the study’s information to other groups that they felt would be interested in participating. An informational letter with a description of the project objectives was included in the invitation. After potential participants read the informational letter and confirmed their interest in participating, they received an informed consent letter to be signed before the interview appointment. In cases where the participant was not able to submit a signed consent letter before the interview, they were asked to verbally provide consent to participate in the study on the day of the interview, which was recorded and stored separately from the recording of the interview itself.

A total of 18 interviews were held comprising 1 to 3 participants per organization, depending on participant availability. The interviews with reception participants were held individually, as they were not representing an organization. Of the 18 interviews, 6 (33%) were held with care organizations, 4 (22%) with technology developers, 3 (17%) with technology integrators, and 5 (28%) with reception. The participants were assigned letters and numbers to deidentify them, ranging from P1 to P25.

The interviews were conducted over Zoom (Zoom Video Communications, Inc) and began with a brief presentation to contextualize the project. Following the presentation, questions were posed using a semistructured interview guide, which allowed for the questions to be adapted to each participant’s context. A basic version of the interview guide was shared with the participants before the interview to give them time to consider the questions. Whenever possible, the interviews were conducted with groups of participants who worked in different positions within the same organization to gather diverse perspectives. Following their interview, the participants received a feedback letter thanking them for their participation, reminding them of the purpose of the study, and providing them with details on confidentiality and ethics.

A thematic analysis of the interview transcripts was then conducted by summarizing the benefits, concerns, and barriers regarding the use of AAL data in the care of older adults and describing the current state of data flow in the context of AAL technologies. This method was chosen for its applicability when identifying topics within semistructured interviews [25,26]. After the first 4 interviews, open coding began, and a set of inductive codes was developed collaboratively with the members of the research team. These codes were revisited and revised iteratively as needed as new concepts emerged in the subsequent interviews. Coding was done using the NVivo software (QSR International) by GBN and HD. Six interviews were chosen at random to be coded by both GBN and HD to ensure consistency. Any discrepancies in coding were discussed between the 2 researchers, and conclusions were then applied to the remaining analysis. After this process, codes were grouped into themes and shared and discussed with the rest of the research team and an advisory panel of experts in older adult care for approval.

**Ethics Approval and Informed Consent**

The procedure of this study and the semistructured interview guide, informed consent letter, and informational letter used in this study were reviewed and provided ethics approval by a University of Waterloo Research Ethics Committee (ORE# 43958). No risks were anticipated in the study, although the participants were warned that, given that they were being interviewed in a group setting, confidentiality could not be guaranteed from the other participants in the interview. No remuneration for participation was offered.

**Results**

During the interviews, the participants described the benefits, concerns, and barriers that they perceived regarding the use of AAL data in the care of older adults. This section is divided among these 3 topics, with further subheadings to distinguish key insights provided by the participants.

**Benefits of AAL Systems**

**Monitoring and Alerting**

The participants outlined several benefits that AAL can provide to the care of older adults at varying points in the continuum of care. The most consistently cited benefit was the potential of sensors and other monitoring technologies to predict and alert care providers and caregivers to incidents in which the care recipient is at risk, such as injury or illness. The system would detect deviations and abnormalities compared with the typical parameter metrics. For example, P11, who came from a technology development organization, described the value of their technology as follows:

> *Most senior people have some chronic condition or multiple chronic conditions, and with good electronic devices, we can collect data on a daily basis so that we can monitor their general health condition and identify problems early, right, before they become a big issue.*

As described here, continuous monitoring can potentially detect when a care recipient is experiencing a decline by detecting deviations and abnormalities compared with their typical parameter metrics. In general, the participants described monitoring as taking 1 of 2 forms. The first was the tracking of regularly measured parameters to examine whether they have exhibited a recent change, with participants describing solutions such as smart thermometers and glucose monitoring (cited by participant P6) or blood pressure monitoring (cited by participant P8); the second was a more sophisticated option in which...
machine learning was used to identify the usual behaviors and patterns of the care recipient to establish a baseline for daily functioning, such as “monitoring activities of daily living” (cited by participant P6), “collecting data on (...) how they’re sleeping, when they’re getting up to go to the bathroom” (cited by participant P2), and “time spent (...) sitting, standing, lying” (cited by participant P11). The latter was described as preferable, as it allows care providers to be more proactive, with participant P4 explaining that “if someone has typically got normal morning routines (...) and you’re not seeing those routines and there’s alerts, we can go check on her” and several participants (participants P2, P8, P15, P21, P22, and P25) noting its potential to promote independence.

Health care providers can receive alerts of incidents, but more importantly, the continuous monitoring of data can accurately capture changes in the health of care recipients. These data can be used to adjust their care plan as needed. Such systems are particularly desirable, as they mitigate the burden of identifying and reporting relevant information about care recipients, especially about care recipients who cannot report on their own well-being because of cognitive or language difficulties. Participant P24 provided the example of a care recipient with a comorbidity of Parkinson disease and dementia who was experiencing issues with their movement (ie, freezing or hyperactivity) stemming from the dose and timing of medication delivery:

The problem with Parkinson’s is by the time you get to that degree of Parkinsonism, you have cognitive issues, and so trying to get people to remember how they were at some time during the day, it’s hard.

The use of AAL would allow for the circumvention of this issue, providing a record of when symptoms occurred that a care provider can then cross-reference against a medication schedule.

**Confidence in Aging in Place**

Another greater confidence in aging in place for both care recipients and their various caregivers. Two participants (P7, who came from a care organization, and P15, a technology integrator) remarked on the potential of technological supports to prevent “premature” moves into assisted care settings, allowing the older adult to be in their preferred space. Beyond the safety and convenience that AAL technologies provide, they can also offer caregivers peace of mind.

P16 (technology integrator) described how caregivers can benefit from AAL technologies:

For a family member or caregiver, being able to actually see the information around daily activities or movement (...) I see that playing important role in elder care so that they can better understand (...) what’s happening with their family member, because oftentimes what we’ve been finding (...) the individual older adult living in their home doesn’t want to share everything that’s happening, they don’t want to tell them about if they had a fall or if they’ve been feeling ill and staying in bed much longer than usual.

This was presented as an opportunity to reduce the burden of reporting among care recipients, as they may not want to share information that will worry their loved ones or make them appear unwell. By contrast, if all is well, the caregiver may feel more comfortable with not intervening and instead allowing the care recipient to continue aging in place.

**Empowerment and Access**

Some participants described how the use of AAL could contribute to greater access and empowerment with regard to care. Rather than going to a different care setting for assessment and adjustments, care recipients can get themselves assessed and their treatment adjusted without traveling and on their own schedule. P10 (technology developer) described these advantages:

Technology allows people who are more vulnerable in many ways to be able to access really quality services within the comfort of their home or wherever they are and get more help in a more real time and sustainable manner. Over time, these interactions add up to better care, more empowered care, more informed care in the long run.

Care recipients could access information about their own well-being in a timely manner and, ideally, in a manner that would be compatible with their health literacy level.

Another benefit highlighted during the interviews was the potential of AAL to not only aid in the management of care but also enrich care recipients’ lives. The participants (P1 and P2, who came from a care organization, and P14 and P16, technology integrators) discussed technologies’ potential to provide entertainment or connection or otherwise help the care recipient work toward something they would be motivated for, in other words, “meeting their motivation” (cited by participant P14).

**Concerns Regarding the Use of AAL Systems in Care**

**Data Governance**

In Ontario, Canada, compliance with the Personal Health Information Act is crucial for health data gathered by devices [27]. When asked about their concerns regarding the current use of data from AAL technologies in care, many participants raised two key questions: (1) who owns and stores the data? and (2) what are they doing with them? The participants from care organizations and technology developers described this question as often being the first question asked when a new technology was proposed for care recipient use. Participant P1 (care organization) expressed further concerns:

Do I really know how things are being regulated, how it’s being stored? Not until I ask about it, right? It’s still very much up to me, and I think that’s by design. I would love to see the conversation shift (to) how information is being stored, or even to servers, like, are the servers in Canada, are they somewhere else? Those types of things are important.

For devices that gather nonhealth data, regulations or guidelines for the use and protection of data are less clearly defined. Participant P18 (a technology integrator) suggested that these
questions reflect care recipients’ and health care providers’ discomfort with using the cloud infrastructure:

I guess the analogy I can give is that people are used to knowing that their data is sitting on a hard drive in the hospital, for example. It is not being sent to some cloud server which is holding data from that hospital, potentially next to someone’s Amazon shopping experience preferences or whatever else, right? And so, I think they there may be concern—I don’t have evidence for this exactly—but there may be some concern about mixed use of the information.

The same participant (P18) noted that users would sign away the rights to their data for their data to be used by algorithm developers and suggested that this might not be something a user would naturally agree to if they were aware of the terms:

We could frame it to them as like they’re accelerating the development of these algorithms by allowing us to use the data, but I’m wondering if there will be some that are hesitant in sort of signing off that data and realizing it’s not only a benefit to them specifically, for example.

However, this concern was not universally shared. Potential care recipients who were also interviewed (participants P21 and P22) did not express opposition to the idea when directly prompted, and a patient advocate (P23) offered a potential explanation:

One of the things that continually comes up (in conversations with policy groups is) people’s dissatisfaction with commercial uses of their health data. Generally speaking, people are totally happy for their deidentified health data to be used to improve health care services, improve public health, and to help other people (...) but when the data are used for commercial ends to make a company money then they just disapprove.

Accountability and Liability

As AAL systems continue to grow, more agents with different foci and concerns will be required. The participants raised concerns about this expansion, noting that when more agents are engaged with the care recipient, it would become more difficult to determine the true source of and, therefore, the solution for an incident. Participant P4, who came from a care organization, provided an example:

If in the unit, as an example, there’s a [proprietary emergency alert device], alerts for water leaks, alerts for smoke detectors. The smoke alarm went off, the toilet flooded, the door was opened. Which health authority does the smoke alarm fall under, the fire department or the infection control?

Furthermore, with alerting systems, there is the question of whether they could be held legally responsible for an incident resulting from a false positive or false negative they flagged. Participant P24 provided examples of how these systems might fail:

If [a technology used to identify aggressive behaviour] were to prompt a response inaccurately, if somebody was not engaging in an aggressive behavior, but a response was prompted against an aggressive behavior by long term care staff, that could cause a confrontation where previously there wouldn’t have been one (...) or having heart rate, blood pressure and weights displayed on the mirror in the bathroom for somebody with congestive heart failure, if there’s an inaccuracy in how that’s conveyed or if those are being built into an interpretive algorithm to indicate when to call a doctor, somebody places their trust in that, and it’s just displayed inaccurately for some reason, then that could cause a major medical event.

Barriers to the Use and Implementation of AAL Systems

Value Trade-off

The participants raised many barriers to the use and implementation of AAL systems. The most heavily discussed of these was the perceived trade-off between the value of the technology and its cost and encroachment on care recipients’ privacy, as this calculation is key to agents’ willingness to invest and engage. Costs here can mean several things, with the most obvious meaning being financial expenses. AAL technologies are often expensive, and as participant P15 (a technology integrator) pointed out, there is little support available for interested users:

Technology is not provided in the form of a prescription. Therefore, there’s no pay model described, so who pays for it is always a big question. Although there could be a long list of benefits and validation as to why this is useful, whether for the health of the home or the health of the person, but the reimbursement model is not existent for it even with valid proof.

Similar concerns were expressed by the members of care organizations, with participant P3 noting that the situation may become further complicated for institutions procuring AAL rather than individual caregivers:

We talked about the cost factor, if it’s a cost that has to be absorbed by the client or its costs absorbed by the organization. Do you recoup the money from that? How does that work?

In addition, the participants expressed that an AAL system needed to be worth the time and effort involved in implementing and maintaining it. Participant P11 (a technology developer) referred to this as an “investment of time,” and participant P24 (a patient advocate) offered insight into what that time might be needed for:

Are providers given resources to adopt new technologies? Are they given extra slack time? Are they given education? Is there extra resource built into their day-to-day work so that they can take on
Finally, regarding the privacy encroachment component of the trade-off, the participants noted that this affects the openness to the technology but emphasized the importance of understanding that the meaning of “privacy” may differ between a care recipient and others. Although the protection of users’ data is important, the focus that emerged in these interviews was more on a reluctance to be “spied on” or “nannied” by caregivers. Participant P17 (a technology integrator) explained this as follows:

[Privacy is] not where your data is going, that doesn’t come up that often to be honest. It’s about what people want. It’s almost like if I want to get up and watch TV at 3 am I don’t need an alert going to my son. I can do whatever I want (...) I have earned the right to do whatever I want.

Decision-making Process

Within an organizational context, the participants discussed issues related to the oversight and management of devices in an AAL system, as well as the expectations of management. Technology developers mentioned roadblocks such as the “long, slow decision chain” (participant P13) and “innovation-averse” nature of the Canadian health care system (participant P10). Furthermore, participant P11 discussed the difficult balancing act that technology developers must perform within the confines of health regulations:

In a long-term care facility, based on their current protocols, the nurse has to visit each room every two hours. If they couldn’t change that policy, that means even if they have new technology (...) they still have to visit this room every two hours. Then this will not save them any labor. (...) But then on the other hand, if the technology is really useful, it can reduce their workload, then the union will object because then some of them might fear they will lose their jobs.

Another aspect of management was the issue of care transitions with AAL systems. Participant P4 (care organization) described it as follows:

Some (devices) take a lot of time and pre-planning to set up into a room (...) but sometimes we get the calls that (a resident) can be released from the hospital, but they need these mechanisms in place, so we need to be able to pivot and set up a unit within hours and sometimes less to be able to accommodate that.

Agents working in care organizations must move swiftly to accommodate care recipients’ changing needs; however, the contexts in which they operate do not always allow for this. The participants expressed confusion regarding processes and procedures, which adds to their perception of effort.

Equity

Although equity was mentioned less frequently than other barriers, issues of equity cannot be ignored. The issue of cost potentially being prohibitive was already discussed; however, it must also be acknowledged that the affordability of devices is impacted by other factors. When defining “barriers,” a patient advocate (participant P23) posited the following:

[Barriers] implies that anything that interferes with use exists on the same plane, whereas (...) we live in a very high-level context that is a particular kind of capitalism, and that system incentivizes particular kinds of people to build particular kinds of technologies.

In some cases, the issues raised by the participants are not simply barriers to overcome but are in fact exclusionary roadblocks. Consideration of how to meet the needs of excluded groups is an important pursuit but may be outside the scope of this study.

Discussion

Overview

This study aimed to obtain recommendations from stakeholders regarding the best practices for system-service integrations for AAL. The recommendations were to align with the needs and capacity of health care and allied health systems. To this end, an exploratory study was conducted to understand stakeholders’ perceptions of and concerns with AAL technology use.

Principal Findings

The participants discussed several potential benefits of the use of AAL systems, paying particular attention to the potential for more continuous monitoring. This may be especially valuable for the care of older adults with chronic conditions, and continuous monitoring could be used to detect when a care recipient is experiencing a decline and allow for more proactive care [28,29]. This relieves some of the burden of reporting from the care recipients themselves, meaning that they are not obligated to remember minute details or admit frailty [29,30]. That being said, any technologies brought into the home, for monitoring or other purposes, must be appropriate for the care recipient’s needs and consider the level of personal privacy and independence they wish to maintain.

Similar to the findings in the literature [13,20-22], one of the barriers discussed by some participants was whether the benefits of AAL systems justified the encroachment, real or perceived, on care recipients’ privacy, as well as the cost of the systems. The participants suggested that this may have been due to a lack of understanding of how these technologies work. Therefore, it would be beneficial to take the time to better inform care recipients of (1) the benefits of collecting data and (2) their own rights to choose and refuse the technology as desired, as well as to know which agents have access to their data. That being said, there was some disagreement regarding who that “privacy” is from, whether it be from external agents wanting access to the data, which is more common in the literature, or from informal care recipients with an interest in the care recipient’s daily activities.

Another part of this challenge is the perceived value of AAL systems when weighed against the financing, time, and resources necessary for their implementation because funding programs for home modifications vary between jurisdictions with no
Some participants expressed a concern that the eagerness to implement more technologically advanced and smart solutions has led to a skipping of “basic tech,” arguing that developers assume a level of competency that is not realistic. However, others argued that assuming that older adults cannot use technologies is agist and that they are highly capable of using technologies if the technologies are designed with their use in mind. Nevertheless, technologies are rarely designed for older adults’ use or able to accommodate the technological limitations of older adults with cognitive or dexterity issues [23,42]. There is also the question of how exactly care providers are expected to use the data from AAL systems. AAL systems generate a very high volume of data, leading to concerns among the interview participants about how these data can be used to improve care and coordination. Specific concerns included how alert fatigue can be prevented and how the data can be interpreted in a manner that is personal to the care of the recipient. Creating strategies for the interpretation of the data with the intended use in mind could then produce alerts for care providers that they could understand, trust, and act on to improve the health or well-being of a care recipient.

**Limitations**

First, although this study used the term barriers for simplicity, the authors acknowledge the point made by participant P23 that this term does not account for the fact that the issues preventing AAL systems’ widespread use are multidimensional and sometimes exclusionary of marginalized groups. The equity aspects of access to AAL technologies in their current form include not being affordable for all, not being feasible for all, and often not being trusted by all [20,22,31]. Second, although the positions of a wide range of stakeholders were sought, it is not possible to conclude that all perspectives were represented. The study attempted to mitigate this by encouraging a debate between colleagues in the group interviews.

**Future Directions**

This research points to a need for better clarity and role definition regarding the use of AAL systems in older adult care. Some pertinent issues include the lack of clarity regarding who can gain access to AAL data, how the data should be interpreted, which agent is responsible for action based on the collected data, and the trade-off of using AAL technologies in care settings. This may be addressed through further interdisciplinary research, including the development of a comprehensive data governance framework for AAL in the continuum of care.

In addition, future work should explore the external influences that guide the development of technologies at large. One such external influence is the fact that AAL development is often funded through a venture capitalist system that incentivizes technology companies to develop particular types of health technologies depending on what is most likely to be funded, rather than depending on evidence-informed needs [43-45]. Researchers should be cautious of assuming that the resources available to caregivers in a high-income, majority White, and socially connected semiurban community are also available to those elsewhere. If only the challenges of adoption and use faced by care recipients in this group are considered, then...
benefits will accrue only for them and enhance the health disparities faced by those who cannot afford AAL systems [31].

Summary of the Findings and Conclusions
This exploratory study used a conceptual framework and interviews with participants to explore the needs and requirements for AAL systems and identify opportunities for standards in this area. The goal was to identify and understand the opportunities for and challenges of integrating these technologies into the health system at the community level (i.e., into the practice of paramedicine and other emergency services, pharmacies, allied health professional services, and medical clinics). The study was conducted in close collaboration with care providers and other stakeholders to ensure that the recommendations for system-service integrations aligned with the needs and capacity of the health care and allied health systems.

The findings from our research have shown that although several potential benefits exist for the use of AAL systems within the continuum of care for older adults, additional work is needed to address concerns and barriers before these benefits can be fully realized. Much of the potential of AAL lies in its ability to support integrated care, meaning continuous and coordinated care that is quick, effective, and includes self-care support, respect for care recipients’ preferences, and appropriate involvement of family members and other informal caregivers [18,19]. AAL can improve care by facilitating better monitoring of care recipients’ health and empowering care recipients to pursue their health goals. However, to accomplish this, further work is necessary to define how data should be managed as AAL systems grow larger and more complex and more agents become involved, with an awareness of the perceptions of care recipients and their care partners as well as the equity issues inherent to AAL technology.

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Data Availability
The data sets generated or analyzed during this study are not publicly available because of confidentiality promised to the participants as part of the informed consent process but are available from the corresponding author upon reasonable request.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Semistructured interview guide.

References


34. Offermann-van Heek J, Ziefe M. They don't care about us! Care personnel's perspectives on ambient assisted living technology usage: scenario-based survey study. JMIR Rehabil Assist Technol 2018 Sep 24;5(2):e10424 [FREE Full text] [doi: 10.2196/10424] [Medline: 30249592]


42. Wegener EK, Bergschöld JM, Whitemore C, Winters M, Kayser L. Involving older people with frailty or impairment in the design process of digital health technologies to enable aging in place: scoping review. JMIR Hum Factors 2023 Jan 27;10:e37785 [FREE Full text] [doi: 10.2196/37785] [Medline: 36705959]


Abbreviations

AAL: active assisted living
IoT: internet of things
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A Tablet-Based App to Support Nursing Home Staff in Delivering an Individualized Cognitive and Physical Exercise Program for Individuals With Dementia: Mixed Methods Usability Study

Jelena Krafft1, MSc; Bettina Barisch-Fritz1, PhD; Janina Krell-Roesch1, PhD; Sandra Trautwein1, PhD; Andrea Scharpf1, PhD; Alexander Woll1, Prof Dr
Institute of Sports and Sports Science, Karlsruhe Institute of Technology, Karlsruhe, Germany

Corresponding Author:
Jelena Krafft, MSc
Institute of Sports and Sports Science
Karlsruhe Institute of Technology
Engler-Bunte-Ring 15
Karlsruhe, 76131
Germany
Phone: 49 721 608 ext 48513
Email: jelena.krafft@kit.edu

Abstract

Background: The promotion of physical activity in individuals with dementia living in nursing homes is crucial for preserving physical and cognitive functions and the associated quality of life. Nevertheless, the implementation of physical activity programs in this setting is challenging, as the time and expertise of nursing home staff are limited. This situation was further exacerbated by the COVID-19 pandemic. Mobile health apps may be a sustainable approach to overcome these challenges in the long term. Therefore, the Individualized Cognitive and Physical Exercise-App (the InCoPE-App) was developed to support nursing home staff in delivering and implementing tailored cognitive and physical exercise training for individuals with dementia.

Objective: This study aims to assess the usability of the InCoPE-App in terms of user performance and user perception in a laboratory setting using a mixed methods approach.

Methods: Nursing home staff were encouraged to perform 5 basic tasks within the InCoPE-App. Their thoughts while using the app were captured by implementing a think aloud protocol. Then, participants completed the System Usability Scale questionnaire. The think aloud transcripts were qualitatively evaluated to unveil usability issues. All identified issues were rated in terms of their necessity to be fixed. Task completion (ie, success rate and time) and perceived usability were evaluated descriptively.

Results: A total of 14 nursing home employees (mean age 53.7, SD 10.6 years; n=13, 93% women) participated in the study. The perceived usability of the InCoPE-App, as assessed by the System Usability Scale questionnaire, can be rated as “good.” The main usability issues concerned navigation logic and comprehensibility of app content.

Conclusions: The InCoPE-App is a user-friendly app that enables nursing home staff to deliver and implement cognitive and physical exercise training for individuals with dementia in nursing homes. The InCoPE-App can be used with little training, even by people aged ≥50 years, who may have low digital literacy. To achieve sustainable use and high user satisfaction of the InCoPE-App in the long term, it should be implemented and evaluated in a field study.

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KEYWORDS
dementia; individualized physical exercise; tailored exercise; physical activity; older adults; app; mobile health; mHealth; usability; mobile phone
Introduction

Background

More than 55 million people worldwide have dementia, with approximately 10 million new cases every year [1]. By 2050, the number of individuals with dementia is expected to increase to up to 150 million individuals worldwide [2,3]. As dementia is a incurable disease, treatment possibilities to stop or slow the progression of disease-specific symptoms (eg, declining cognitive function and physical performance) are critical. In addition to pharmacological therapies, nonpharmacological approaches such as physical activity (PA) have gained increasing attention. A growing body of research has shown that PA may have a beneficial impact on cognitive and physical performance in individuals with dementia [4]. However, only small and mainly nonsignificant effects of PA on quality of life (QoL) among individuals with dementia have been reported [5,6]. Overall, results from studies are conflicting, mainly owing to heterogeneous sample sizes and characteristics and differing intervention periods, contexts, frequency, and duration of PA training [4]. Some studies also pointed out the heterogeneous prerequisites of individuals with dementia such as varying interindividual degrees of cognitive and motor impairments. Thus, a one-size-fits-all PA approach may fall short [7]. In addition, individual vulnerabilities and needs of individuals with dementia may need to be considered when designing, planning, and conducting PA interventions [8-10].

According to several studies [11-14] and a systematic review [15], up to 80% of individuals living in nursing homes in European countries experience dementia. Individuals with dementia residing in nursing homes often have decreased life expectancy [16], more advanced dementia stages, and more impaired physical performance compared with community-dwelling individuals with dementia [17]. Moreover, living in a nursing home is associated with negative changes in QoL. [18]. Overall, promoting PA in nursing home settings is therefore crucial. In many nursing homes, PA promotion is not regarded as a task or responsibility of nursing home staff and is usually delegated to external providers (eg, physiotherapists) [19]. During the COVID-19 pandemic, this practice was no longer feasible, as many nursing homes in Germany and other European countries were closed to visitors or external service providers, and PA programs had been discontinued in many nursing homes owing to increased safety measures [19]. The resulting social isolation and restricted movement possibilities led to worsening of cognitive function and physical performance among individuals with dementia, as perceived by nursing home staff [20]. Moreover, some studies reported significant impact on the mental well-being of nursing home residents (eg, QoL) [21]. A conclusion that can be drawn from the COVID-19 pandemic with its far-reaching health consequences is that PA promotion in nursing homes should be designed and implemented in a way that allows continuation even as new challenges arise (eg, changing circumstances owing to the pandemic or similar events) and without access to external PA instructors. Therefore, mobile health (mHealth) apps may be a viable solution in this context. Various definitions of the term mHealth exist and most include key aspects such as mobile computing, medical sensor, and communications technologies [22], health information and services [23], patient monitoring devices, and personal digital assistants [24] to improve health outcomes. mHealth can be considered as a subsection of eHealth [23]. mHealth solutions are considered to be feasible, can be implemented at little or no cost [25], and have wide reach among various patient groups or populations.

So far, a large number of mHealth apps for use in care settings are available, with most of them providing support for medication management or health information, and they can be accessed free of charge from app stores [26]. However, to the best of our knowledge, no mHealth app for individualized PA promotion in nursing homes is available so far [27]. mHealth apps are promising tools in this setting and may help alleviate nursing home staff shortages; for example, a standardized, mHealth-based training manual may facilitate the instructions of PA sessions. Moreover, such an app may contain pictures and detailed exercise descriptions and information about the possible risk factors of certain exercises. These advantages may reduce the potential barriers for nursing home employees to deliver PA programs to individuals with dementia and enable the implementation of PA even in times of a pandemic. Nevertheless, a recent Cochrane review showed that health care workers with limited experience in using mobile apps and low digital literacy had concerns about making mistakes when using a mobile device [28], which might, in turn, affect the usability and acceptability of such apps.

However, to guarantee the long-term use and acceptability of mHealth apps in nursing homes, the feasibility and usability of an app must be considered, ideally in the design and development phase of the app [29]. Usability indicates how a product is perceived by an intended user to achieve a specific goal in a specific context of use [30]. Nevertheless, most of the currently existing mHealth apps have not been scientifically designed and empirically evaluated [31,32], and publications addressing their feasibility and usability are lacking [33]. This is a main research gap, particularly because theory-based design and development of apps with subsequent scientific evaluation of usability and acceptability may be among the most important criteria to ensure the long-term implementation of mHealth apps, particularly in special settings such as nursing homes [34]. Moreover, studies have shown that involving nursing home staff in the development process of a mobile app makes them feel valuable and appreciated, which, in turn, could have a positive impact on acceptance [35]. Therefore, an iterative development process of an app including qualitative and quantitative methods to integrate possible end users in the development process is recommended [36], where designing, testing, and redesigning of a mobile app are embedded in a regular circle [29]. Examples for qualitatively collected data could be the identification of specific problems. In contrast, quantitative data may provide insight into use times or success rates [33]. A multistep development approach is intended to increase end users’ acceptability of an mHealth app and to ensure long-term use.
Objective
To address the current need for a scientifically derived mHealth-based PA promotion for individuals with dementia in nursing homes, we developed the Individualized Cognitive and Physical Exercise-App (the InCoPE-App). The InCoPE-App is a tablet-based app aimed at assisting nursing home staff in delivering tailored cognitive and physical exercise training for individuals with dementia in a nursing home setting. The content of the InCoPE-App is based on previous studies of our research group on PA for individuals with dementia [8-10]. The goal of this study was to evaluate the usability of the InCoPE-App with possible end users, that is, nursing home staff, using a mixed methods approach in a laboratory setting. Specifically, we examined user performance and perception, existing problems, and possible solutions regarding the InCoPE-App by integrating qualitative and quantitative methods. The results of this study will be used for further improvement and adaption of the InCoPE-App with the ultimate goal of implementation and long-term use of the app in nursing homes. Furthermore, this procedure can be used as an example for future studies of app development in nursing home settings.

Methods

Study Design and Participants
To evaluate the usability of the InCoPE-App, we used a mixed methods approach. We used a combination of qualitative and quantitative methods and considered a sample of 14 individuals, as previous studies have shown that 8 participants are sufficient to identify the main usability problems of a system [37]. Participants were recruited in April 2021 from 5 nursing homes in South-Western Germany. To be included in the study, participants (ie, nursing home staff) were required to have had previous experience with PA programs for individuals with dementia in an easy and low-threshold way. Importantly, the InCoPE-App can be used by staff without previous PA-specific training or expertise.

Ethics Approval
The study was approved by the Ethics Committee of the Karlsruhe Institute of Technology (Karlsruhe, Germany).

The InCoPE-App: Content and Development
The InCoPE-App was designed to be used by nursing home staff and not by individuals with dementia themselves, as individuals with dementia in nursing homes would not be able to perform structured physical exercise alone, and they need supervision for safety reasons. Specifically, the InCoPE-App supports nursing home staff in assessing current levels of cognitive and physical performance of individuals with dementia and, based on this assessment, guiding and delivering physical exercise sessions to individuals with dementia, without the need of having completed specific training or certification in sports or exercise science or kinesiology. A unique feature of the InCoPE-App is its integrated algorithm that uses data from 1 cognitive (ie, Mini Mental Status Examination [38]) and 3 physical performance tests (ie, Frailty and Injuries: Cooperative Studies of Intervention Techniques [39], 6-meter walk test [40], and modified 30-second chair stand test [41,42]) to tailor the recommended exercise program to the participant’s individual needs (Figure 1). The cognitive and physical tests integrated into the InCoPE-App are oriented to recommendations for individuals with dementia [43,44]. On the basis of the individual performance results, each individual with dementia is assigned to one of four exercise clusters, which are integrated in the app [45]: (1) individuals with below-average cognitive and physical performance, (2) individuals with average cognitive performance and above average physical performance, (3) individuals with above average cognitive performance and below average physical performance, and (4) individuals with above average cognitive and physical performance. The clustering into these 4 groups is based on previous studies by our group that have demonstrated the need for individualization of PA programs for individuals with dementia [8-10,46]. Depending on the cluster assignment, the InCoPE-App generates an exercise plan that fits the current performance level and needs of the individual with dementia. To adjust the exercise plan to individual changes in cognitive and physical performance, the InCoPE-App reminds the nursing home staff to repeat and record cognitive and physical performance tests every 3 weeks. In general, the exercise plan integrated into the InCoPE-App consists of ritualized warm-up and cooldown and 2 individualized workout phases that integrate exercises for balance, mobility, and upper and lower body strength [45].

The generated exercise plan is presented in the app through brief descriptions along with pictures of the exercises to provide guidance about how to perform the exercises correctly and avoid common mistakes (Figure 2). Each training session lasts 60 minutes and is intended to be performed in one-on-one sessions or small groups of up to 2 individuals with dementia. For more information about the main functions of the InCoPE-App, refer to Multimedia Appendix 1.

The iterative development process of the InCoPE-App included several steps (Figure 3), of which 3 are already completed. First, we defined a general product vision of the InCoPE-App. We then conducted a web-based survey to collect information about sex, age, profession, and daily tasks from nursing home staff. Furthermore, we gathered information about potential previous implementations of PA programs or interventions in participants’ nursing homes. On the basis of the results of this study, we were able to sketch personas as possible end users of the InCoPE-App [26]. In the second step, based on our product vision and the design of personas, we developed the first prototype of theInCoPE-App 1.0 in collaboration with a software expert team. The InCoPE-App was developed on Android 9.0. For
study purposes, an offline-capable version of the InCoPE-App was locally installed on tablets (Lenovo Tab M10; 10 inch). Currently, the app is available only in German. The usability of the InCoPE-App 1.0 was tested by 7 experts in the areas of psychology, IT, sports science, and software development using a think aloud protocol and the System Usability Scale (SUS) [47]. The expert review unveiled relevant information about the usability of the InCoPE-App. The experts rated the InCoPE-App as acceptable but also noted some usability problems.

**Figure 1.** Chair stand test. (A) Written and illustrated description of the test procedure; (B) description of the measurement recording; (C) input field for the measured value; (D) integrated stop watch; and (E) required tools or equipment and possible risks.

**Figure 2.** Exercise for lower limb strength. (A) Overview of the training schedule; (B) exercise sequence in pictures; (C) description of aims and correct conduct of the exercise; (D) training parameters (eg, repetitions), possible risks (eg, pain), and cognitive input (eg, counting the repetitions); and (E) further information (eg, required equipment).
Outcomes and Procedure

After the participants signed the consent form, demographic information and data about general smartphone, tablet, and app use were collected from each participant using a short survey. Usability was assessed qualitatively and quantitatively in individual sessions during the first use of the InCoPE-App. To collect qualitative usability data, the think aloud technique was applied as it was found to be the most frequently used qualitative approach in usability testing of eHealth applications [31]. At the beginning, we explained to the participants that they would be required to speak their running thoughts aloud while interacting with the InCoPE-App. To become familiarized with this method, participants received a sample task within the InCoPE-App (ie, “Go to 'exercise pool,' choose exercise 'Rope Pulling' and tell me possible risks of this exercise”). Then, they were asked to perform 5 tasks (Table 1) with the InCoPE-App along a standardized protocol. These tasks were representative of a real-world situation when using the InCoPE-App in the nursing home setting [37]. During the think aloud session, a researcher was present and only interrupted participants if they stopped talking for >10 seconds while performing the tasks. Running thoughts of the participants were recorded via a voice recorder. Following the think aloud session, participants were asked three final questions: (1) “Which parts of the InCoPE-App are well designed?” (2) “Which parts of the InCoPE-App need to be revised?” and (3) “Do you have any other further comments on the InCoPE-App?”

For quantitative usability assessment, the time spent on each individual task and all tasks overall was assessed by using the screen recorder function of the tablet. Furthermore, the success rate of each task was coded as “success,” “problem,” or “failure,” as described by Ehrler et al [48]. After the think aloud protocol, participants completed the German version of SUS [49,50], which is one of the most frequently used questionnaires in usability research [31]. The German version of SUS has reasonable reliability (0.84), concurrent validity (0.74), and sensitivity (0.83) [50]. SUS comprises 10 statements about the usability of a system (eg, “I think that I would like to use this system frequently”), each rated on a scale ranging from “I don’t agree” to “I totally agree.” Negatively worded statements (even numbers) are coded from 4 to 0, whereas positively worded (odd numbers) statements are coded from 0 to 4 [51]. The items are added to a sum score (minimum 0; maximum 40 points), which is multiplied by 2.5 (sum score—minimum 0; maximum 100 points). Published literature suggests a mean SUS score of 68 as a useful “benchmark” [52]. Furthermore, the total SUS score can be interpreted as follows: scores <60 indicate substantial usability problems, scores between 60 and 80 indicate marginal to good usability, and scores >80 indicate good to excellent usability of a system [49]. According to the Subjective Rating Scale of Bangor et al [53], a mean SUS score of 71.4 indicates good usability.
Table 1. Standardized “think aloud” protocol.

<table>
<thead>
<tr>
<th>Task</th>
<th>Description of the task</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>“Create a new test person.”</td>
</tr>
<tr>
<td>2</td>
<td>“Start and complete cognitive and physical testing with the test person.”</td>
</tr>
<tr>
<td>3</td>
<td>“Create an exercise plan and replace two exercises.”</td>
</tr>
<tr>
<td>4</td>
<td>“Start and finish a training session with the test person.”</td>
</tr>
<tr>
<td>5</td>
<td>“Start and finish a training session with two participants simultaneously.”</td>
</tr>
</tbody>
</table>

Data Collection and Analysis

Each think aloud session and the 3 interview questions were recorded with a voice recorder (Philips DVT2050) and transcribed verbatim using a transcription software (software F4transkript, from audiotranskription, dr.dresing&pehl GmbH). The transcribed protocols contained time stamps to estimate the time for task completion. To identify usability problems, bottom-up developed categories (ie, navigation, screen layout, graphics, comprehensibility, and overall usability) were used to analyze the protocols divided according to the think aloud tasks. This categorization was adjusted and based on a proposal by Kushniruk and Patel [54]. Two researchers (JK and ST) coded the transcripts independently. In case of ambiguities and discrepancies, a third researcher (BBF) was consulted. The identified usability problems were further rated by 1 researcher (JK) using the Nielsen severity scale (0=I do not agree that this is a usability problem at all, 1=cosmetic problem only, 2=minor usability problem, 3=major usability problem, and 4=usability catastrophe) [55]. This allows ranking of the usability problems and helps to prioritize them for a further revision cycle of the InCoPE-App. For presentation in this paper, the quotations from the final interviews were translated from German to English.

The total SUS score, time spent on each task and in total (derived from the screen records), and frequencies of identified usability problems were evaluated descriptively (mean, SD, and range) using SPSS (version 27.0; IBM Statistics). The success rate for each task was evaluated in percentages.

Results

Participants

We included 14 employees (n=13, 93% women and n=1, 7% men) from 5 nursing homes. The mean age was 53.7 (SD 10.6) years. Data about general smartphone and tablet use showed that all participants (14/14, 100%) owned a smartphone, with 93% (13/14) of the participants reporting daily use. Only 21% (3/14) of the participants reported using a tablet. Of the 14 participants, 12 (86%) had several apps installed on their personal smartphones or tablets and 7 (50%) reported daily app use. For study purposes, all participants (14/14, 100%) used the InCoPE-App installed on a tablet. Participants’ demographics and information about technical experience are presented in Table 2.
Table 2. Sample characteristics (N=14).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>53.7 (10.6)</td>
</tr>
<tr>
<td><strong>Sex, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>13 (93)</td>
</tr>
<tr>
<td>Male</td>
<td>1 (7)</td>
</tr>
<tr>
<td><strong>Age group (years), n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>1 (7)</td>
</tr>
<tr>
<td>30-39</td>
<td>1 (7)</td>
</tr>
<tr>
<td>40-49</td>
<td>1 (7)</td>
</tr>
<tr>
<td>50-59</td>
<td>6 (43)</td>
</tr>
<tr>
<td>&gt;60</td>
<td>5 (36)</td>
</tr>
<tr>
<td><strong>Certificate of secondary education, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Hauptschule (diploma after 5 y)</td>
<td>5 (36)</td>
</tr>
<tr>
<td>Realschule (diploma after 6 y)</td>
<td>2 (14)</td>
</tr>
<tr>
<td>High school diploma (diploma after 8-9 y; university entrance qualification)</td>
<td>5 (36)</td>
</tr>
<tr>
<td>University degree</td>
<td>2 (14)</td>
</tr>
<tr>
<td><strong>Use of mobile devices, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Smartphone</td>
<td>14 (100)</td>
</tr>
<tr>
<td>Tablet</td>
<td>3 (21)</td>
</tr>
<tr>
<td><strong>Frequency of smartphone use, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>13 (93)</td>
</tr>
<tr>
<td>Several times/wk</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Several times/mo</td>
<td>—</td>
</tr>
<tr>
<td>Rarely</td>
<td>—</td>
</tr>
<tr>
<td>Never</td>
<td>—</td>
</tr>
<tr>
<td><strong>Frequency of tablet use, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Several times/wk</td>
<td>2 (14)</td>
</tr>
<tr>
<td>Several times/mo</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Rarely</td>
<td>—</td>
</tr>
<tr>
<td>Never</td>
<td>10 (71)</td>
</tr>
<tr>
<td><strong>Use of apps, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>12 (86)</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency of mobile app use, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Daily</td>
<td>7 (50)</td>
</tr>
<tr>
<td>Several times/wk</td>
<td>3 (21)</td>
</tr>
<tr>
<td>Several times/mo</td>
<td>—</td>
</tr>
<tr>
<td>Rarely</td>
<td>2 (14)</td>
</tr>
<tr>
<td>Never</td>
<td>—</td>
</tr>
</tbody>
</table>

*aNot applicable.*

**SUS Scores**

The mean SUS score was 72.3 (SD 18.9; range 45-95), indicating good to marginal usability. According to the Adjective Rating Scale by Bangor et al [53], usability can be rated as good. When dividing the sample into 3 age groups (ie, nursing home staff aged <50 years: 4/14, 29%; aged between 50 and 60 years: 5/14, 36%; and aged >60 years: 5/14, 36%), the mean SUS...
scores were 77.5 (SD 16.2), 78 (SD 17.1), and 60 (SD 22.1), respectively, indicating better usability in participants aged <60 years. The results for single items of the SUS are presented in Table 3.

**Table 3.** Scores for the single items of the System Usability Scale.

<table>
<thead>
<tr>
<th>Item</th>
<th>Statement</th>
<th>Score of the total group (N=14), mean (SD)</th>
<th>Score of participants aged ≤50 years (n=4), mean (SD)</th>
<th>Score of participants aged 51-59 years (n=5), mean (SD)</th>
<th>Score of participants aged ≥60 years (n=5), mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>“I think that I would like to use this system frequently.”</td>
<td>3.2 (1)</td>
<td>3.5 (0.6)</td>
<td>3.6 (0.9)</td>
<td>2.6 (1.1)</td>
</tr>
<tr>
<td>2</td>
<td>“I found the system unnecessarily complex.”</td>
<td>2.9 (1.2)</td>
<td>3.3 (1)</td>
<td>2.6 (1.7)</td>
<td>2.8 (1.1)</td>
</tr>
<tr>
<td>3</td>
<td>“I thought the system was easy to use.”</td>
<td>2.8 (0.7)</td>
<td>3 (0.8)</td>
<td>3 (0.7)</td>
<td>2.4 (0.5)</td>
</tr>
<tr>
<td>4</td>
<td>“I think that I would need the support of a technical person to be able to use this system.”</td>
<td>2.7 (1.4)</td>
<td>3.8 (0.5)</td>
<td>2.6 (1.3)</td>
<td>2 (1.6)</td>
</tr>
<tr>
<td>5</td>
<td>“I found the various functions in this system were well integrated.”</td>
<td>3.1 (0.8)</td>
<td>3 (0.8)</td>
<td>3.4 (0.5)</td>
<td>2.8 (1.1)</td>
</tr>
<tr>
<td>6</td>
<td>“I thought there was too much inconsistency in this system.”</td>
<td>3.2 (0.7)</td>
<td>3.3 (0.5)</td>
<td>3.4 (0.9)</td>
<td>3 (0.8)</td>
</tr>
<tr>
<td>7</td>
<td>“I would imagine that most people would learn to use this system very quickly.”</td>
<td>3.2 (0.8)</td>
<td>3.3 (1)</td>
<td>3.6 (0.5)</td>
<td>2.8 (0.8)</td>
</tr>
<tr>
<td>8</td>
<td>“I found the system very cumbersome to use.”</td>
<td>2.9 (1.1)</td>
<td>2.5 (1.3)</td>
<td>3.0 (1.2)</td>
<td>3.0 (1)</td>
</tr>
<tr>
<td>9</td>
<td>“I felt very confident using the system.”</td>
<td>2.4 (1)</td>
<td>2.8 (0.5)</td>
<td>2.8 (0.8)</td>
<td>1.6 (1.1)</td>
</tr>
<tr>
<td>10</td>
<td>“I needed to learn a lot of things before I could get going with this system.”</td>
<td>2.9 (1)</td>
<td>2.8 (1.3)</td>
<td>3.2 (0.8)</td>
<td>2.6 (1.1)</td>
</tr>
</tbody>
</table>

\(^a\)Total mean 72.3 (SD 18.9).
\(^b\)Total mean 77.5 (SD 16.2).
\(^c\)Total mean 78 (SD 17.1).
\(^d\)Total mean 60 (SD 22.1).

**Think Aloud Session and Final Interviews**

The mean duration of the think aloud sessions in total was 45 minutes and 56 seconds (SD 5 min and 42 s; range 33 min and 34 s to 53 min and 7 s), including the instructions and the familiarization task at the beginning. The most time-consuming part was cognitive and physical testing (mean 16 min and 26 s, SD 3 min and 44 s; Table 4). Creating a test person profile was completed by all participants without any problems. Most usability problems (n=71) arose with cognitive and physical testing. The last task (“Start and finish a training with two participants simultaneously”) could not be performed by any participant (Table 4).

On the basis of the think aloud protocols, 71 different usability problems could be identified that were mentioned 134 times in total. The categorization of the usability problems according to Kushniruk and Patel [54] revealed most problems in the category, “navigation” (64/134, 47.8%), within the InCoPE-App. In particular, problems with finding the button to start a training for 2 participants simultaneously were mentioned by 79% (11/14) of the participants. The frequency of the mentioned problems and the most common examples are displayed in Table 5.

**Table 4.** Task duration and task completion.

<table>
<thead>
<tr>
<th>Task</th>
<th>Duration, mean (SD)</th>
<th>Completion (N=14), n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Create a new test person.”</td>
<td>3 min, 53 s (2 min, 4 s)</td>
<td>14 (100)</td>
</tr>
<tr>
<td>“Start and complete cognitive and physical testing with the test person.”</td>
<td>16 min, 26 s (3 min, 44 s)</td>
<td>3 (21)</td>
</tr>
<tr>
<td>“Create an exercise plan and replace two exercises.”</td>
<td>3 min, 54 s (1 min, 36 s)</td>
<td>3 (21)</td>
</tr>
<tr>
<td>“Start and finish a training session with the test person.”</td>
<td>5 min, 14 s (2 min, 19 s)</td>
<td>2 (14)</td>
</tr>
<tr>
<td>“Start and finish a training session with two participants simultaneously.”</td>
<td><em>a</em></td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

\(^a\)Not applicable.
Table 5. Frequency and rating of the mentioned usability problems identified via the think aloud protocol.

<table>
<thead>
<tr>
<th>Category</th>
<th>Mentioned frequency (N=134), n (%)</th>
<th>Most common problems and rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navigation</td>
<td>64 (47.8)</td>
<td>• Finding the start button to initiate a training for 2 people—“Usability catastrophe”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Changing or replacing exercises in an exercise plan—“Major usability problem”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Noticing the stopwatch during assessment—“Usability catastrophe”</td>
</tr>
<tr>
<td>Screen layout</td>
<td>20 (14.9)</td>
<td>• Small font type—“Major Usability Problem”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Overloaded screens during exercising—“Major Usability Problem”</td>
</tr>
<tr>
<td>Graphics</td>
<td>6 (4.5)</td>
<td>• No “zoom in” function—“Cosmetic problem only”</td>
</tr>
<tr>
<td>Comprehensibility</td>
<td>28 (20.9)</td>
<td>• Uncertainty in cognitive test procedures—“Usability catastrophe”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Unclear scientific terminology—“Major Usability Problem”</td>
</tr>
<tr>
<td>Overall usability</td>
<td>16 (11.9)</td>
<td>• Drag-and-drop function is not intuitive—“Minor usability problem”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lot of information on most of the screens, owing to which app use was perceived</td>
</tr>
<tr>
<td></td>
<td></td>
<td>as time consuming—“Minor usability problem”</td>
</tr>
</tbody>
</table>

Of the 71 identified usability concerns, 4 (6%) were rated as usability catastrophe according to Nielsen 48 and must be corrected before the InCoPE-App can be used in the field. Of the 71 problems, 29 (41%) were rated as a major usability problem with high priority to fix; 23 (32%) as minor usability with low priority to fix; and 8 (11%) as cosmetic problems only, which should only be fixed if there will be extra time for app development. Of the 71 problems, 7 (10%) mentioned usability concerns were rated as not a usability problem at all. Examples are displayed in Table 5.

During the final interviews, participants were able to explain which parts of the InCoPE-App were well designed. They explicitly mentioned that creating a test person within the InCoPE-App was very simple and easy to conduct:

I think, the beginning, when creating a participant profile – this was very good and clear.

Moreover, the participants highlighted the good interface and the clear user paths within the InCoPE-App:

I liked that it [the app] is well pictured.

What I totally like is that something is highlighted in orange, when I have to do [enter] something...and it is suggested to me.

The participants also liked the instructions on the training screens within the InCoPE-App:

So you’re just being carried through the exercise plan, exercise by exercise. That is well designed.

[The exercise plan] is already divided into what counts as warm-up, the workout part itself, and the cool-down. I found that to be very clear.

Overall, the participants appreciated that using the app only needs little practice and is beginner-friendly:

I generally have very little idea about a tablet or a smartphone... For me it was plausible. It [the app] has also actually indicated to me what I have to do next.

You also tried to keep it as simple as possible.

In addition to the question about the parts of the InCoPE-App they liked the most, the participants were asked to name the parts that need to be revised in their opinion. Regarding this aspect, it was mentioned that exercise videos instead of pictures would be more user-friendly:

It [the training] would take too long with the participant. I would be lost in details. Videos and especially a voice explaining it [the exercises] to me briefly, that would be very helpful for me.

This statement was accompanied by comments about information overload on the screens within the InCoPE-App:

That is a lot of text. You lose a lot of time. By the time I read this, the participants no longer have any desire [to exercise]

I would have liked it better if the text had been shortened and presented in sections.

In contrast to the comments about the beginner-friendliness of the InCoPE-App, a person also mentioned barriers to the first use:

Well, if you don’t use a tablet every day, you don’t know where to push [a button]. For me as a person with limited media experience, it was hard.

Finally, when participants were asked for further comments about the InCoPE-App, they underlined that even though they had some problems with the app at first or with technologies in general, they liked the app:

At the beginning, I was really concerned. I thought that I have no idea about computer and tablets and so on...And I think, this is a great application, even I can handle that.

Discussion

Principal Findings

Promoting physical and cognitive exercise for individuals with dementia in nursing homes is critically important, particularly in terms of the reduction of PA in this setting during the COVID-19 pandemic. Nevertheless, most interventions available
today have limitations regarding long-term use and implementation. With the InCoPE-App, we aimed to develop an effective and easy-to-use app that requires a multistage development process considering feedback from future end users. In this study, we analyzed the usability of the InCoPE-App, which assists nursing home staff in delivering a tailored cognitive and physical exercise program for individuals with dementia in nursing homes.

Here, we applied a mixed methods approach to get an in-depth impression of how the InCoPE-App is perceived by potential end users. Our results show that the usability of the InCoPE-App can be rated as “good” [53]. Considering the results of the single items of SUS, the least agreement was given to the statement, “I felt very confident using the system.” In contrast, the highest agreement was given to the statements, “I would imagine that most people would learn to use this system very quickly” and “I think I would like to use this system frequently.” These results indicate that on the one hand, participants felt that they needed additional information or training with the InCoPE-App. However, in contrast, they assumed that app use can be learned quickly. Overall, participants would like to use the InCoPE-App frequently and did not find the app to be unnecessarily complex.

On the basis of think aloud task completion, cognitive and physical testing required the most time. It can be assumed that this corresponds well with real-life situations, as conducting tests among individuals with dementia requires a rather large amount of time and personnel resources. We observed that, particularly, reading test instructions was time consuming. However, it is likely that time to read instructions within the InCoPE-App may decrease with more regular app use. The most difficult task (100% failure) was to start a simultaneous training of 2 individuals. This app feature needs to be revised with high priority and has to be placed more prominently within the app menu. Overall, we can assume that the InCoPE-App is a user-friendly tool and that most of the problems mentioned by participants could be solved by frequent app use.

Comparison With Previous Studies

Although mobile devices have become increasingly popular over the past decade [28], so far, there is no scientifically evaluated mHealth app available in the context of PA promotion in nursing homes [27]. To the best of our knowledge, our study is the first to evaluate the usability of an mHealth-based app, developed to assist nursing home staff in implementing tailored cognitive and physical exercise for individuals with dementia in nursing homes. A unique feature of the InCoPE-App is that it is not used by the group considered vulnerable (ie, individuals with dementia) directly but by nursing home staff who serve as a mediator. To the best of our knowledge, there are no studies that have used this approach.

The methods used in our study are consistent with the current literature and recommendations for usability testing [37]. Both applied methods exhibit important advantages in gathering a comprehensive impression of the usability of the InCoPE-App. So far, SUS is the most frequently applied questionnaire in the usability testing of digital health solutions [31]. Although there are usability scales specialized tailored for mHealth solutions (eg, mHealth Usability Questionnaire [56]), these newly developed scales have not been widely used, and only a few comparative studies exist [57]. As the sole administration of SUS as a stand-alone usability method is not recommended [58], using a think aloud protocol is a complementary approach that provides direct insight into a person’s cognitive and problem-solving processes while using an app and is therefore essential and effective for uncovering usability issues in addition to a quantitative questionnaire [37,58]. A recent systematic review showed that, even for the evaluation of usability among older participants, questionnaires and qualitative assessments such as think aloud protocols are commonly used and feasible methods [59]. Furthermore, other studies in the context of health care rehabilitation also used a mixed methods approach to assess usability [48,60,61).

In our study, we obtained a mean SUS score that is slightly above the benchmark of 68 points according to Sauro and Lewis [52] and the mean SUS for “good” usability according to Bangor et al [53]. A recent meta-analysis by Hyzy et al [62] explicitly focused on the SUS sum scores of 114 digital health apps and reported a mean score of 76.16 (SD 15.12) for all the included apps. By further categorizing the included apps, they observed a mean SUS score of 83.28 (SD 12.39) for “physical activity” apps (n=66) and a mean SUS score of 71.3 (SD 12.72) for “health care” apps [62]. Owing to the unique content of the InCoPE-App, the content-related results of the think aloud protocols and task completion are not comparable with other studies. Nevertheless, a study by Ehrler et al [48], which examined a mobile app for nurses in a hospital setting, identified “navigation within an app” to be one of the major problems. This is consistent with our results, as 47.8% (64/134) of the problems mentioned by study participants were related to the navigation structure within the InCoPE-App. These results imply that mobile apps to be used by staff in health care settings should be intuitive to navigate because complex navigation is perceived as time consuming and may thus be a barrier for long-term use by the end users [63]. Nevertheless, as the usability results of our study can be interpreted as “good,” we assume that the InCoPE-App is well designed and suitable for its primary target group, that is, nursing home staff.

The perceived usability of the InCoPE-App could also be related to the mean age and the experience with mobile apps in our sample, that is, participants aged <60 years had fewer problems with using the InCoPE-App when compared with those aged >60 years. This was also observed in another study, where older participants reported more usability problems than younger ones, who were also more likely to have used apps before study participation [48]. Furthermore, existing literature has already demonstrated generational differences and a high likelihood of problems when implementing digital (health) solutions among older adults [33,64]. Thus, an age-based digital divide in mHealth adoption has been proposed in the literature [65]. Moreover, individuals often experience a loss in digital literacy if and when they do not use digital devices on a regular basis [28]. To overcome possible age-related and experience-related barriers to app use, current literature recommends education and familiarization training [48,66]. Moreover, as the fear of making mistakes could also be perceived as a barrier [28], “undo” functions should be included in an app [48].
Strengths and Limitations

The main strength of our study is the novelty of the presented InCoPE-App and its user-centered development and testing process. This helps to gain new insights into a, thus far, little-explored research field. Although our participants were predominantly women and aged >50 years, they can be considered to be representative of the population of end users (ie, nursing home staff) who will use the system in the future. It is very crucial to include a representative target group to generate valid usability data and to avoid biases [37]. In addition, our sample was heterogeneous in terms of age, education, and technical experience. This allowed us to detect usability problems from different perspectives and gave us a nuanced impression of the potential end users. Moreover, engaging individuals with less access to or knowledge about technology is very important to ensure high usability of a system for individuals with low digital literacy [67]. Another strength of the study is the mixed methods approach. Particularly in usability research, 1 method alone is not suitable to cover all the important aspects of a system’s usability. Combining SUS with the think aloud task and the interview questions therefore allowed us to gain deep insight into the usability problems, as opposed to only evaluating usability on the basis of a sum score.

A limitation of our study is the relatively late inclusion of the end users in the direct development process of the InCoPE-App. Although we created fictitious end users on the basis of a questionnaire in early development stages [26], the main content and the basic structure of the data model has been developed and finalized without the input of nursing home staff. In other studies, end users were included from the very beginning of the app development process [60]. It is likely that some of the frequently mentioned usability problems (eg, navigation within the app) could have been avoided by the early inclusion of end users in the development process. Another limitation is that members of our research team ranked the usability problems according to the method of Nielsen [55], and it is possible that the end users would have rated the severity of the problems differently. Thus, the revision of the app based on the prioritization done by the researchers may not fully correspond to the expectations and wishes of the end users as they may have chosen another prioritization. Therefore, in future studies, end users should also be included in this step. Furthermore, it should be differentiated which usability problems should be further addressed from different perspectives (eg, experts, developers, researchers, and end users).

Conclusions

The InCoPE-App is a novel and innovative app that assists nursing home staff in delivering tailored cognitive and physical exercise to individuals with dementia residing in nursing homes. We showed that the usability of the current version of the InCoPE-App can be rated as good according to 14 potential end users. Furthermore, even older participants found the InCoPE-App easy to use after some familiarization. Nevertheless, certain aspects such as navigation features within the app must be further improved to increase the usability of the app in the future. To overcome potential barriers to using the app, further development should follow a “less is more” approach, for example, by minimizing navigation screens or reducing the complexity and length of text on the screens. Overall, the inclusion of end users in the app’s development process continues to be critically relevant and highly important. Therefore, the InCoPE-App was further tested in an 18-week intervention study [68].

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Authors’ Contributions

All authors (JK, BB-F, JK-R, AS, ST, and AW) contributed to the conception, design, and implementation of the study. JK, BB-F, and AS collected the data. JK, ST, and BB-F analyzed and interpreted the data. JK wrote the manuscript, and all authors provided critical feedback. All authors approved the final version of the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1


References


42. Trautwein S, Barisch-Fritz B, Scharpf A, Trautwein S, Krell-Roesch J, Woll A. Usability and effectiveness of an individualized, tablet-based, multidomain exercise program for people with dementia delivered by nursing assistants: protocol for an
evaluation of the InCoPE-app. JMIR Res Protoc 2022 Sep 26;11(9):e36247 [FREE Full text] [doi: 10.2196/36247] [Medline: 36156463]


60. Rai HK, Schneider J, Orrell M. An individual cognitive stimulation therapy app for people with dementia: development and usability study of thinkability. JMIR Aging 2020 Nov 16;3(2):e17105 [FREE Full text] [Medline: 36156463]


Abbreviations

the InCoPE-App: the Individualized Cognitive and Physical Exercise-App
mHealth: mobile health
PA: physical activity
QoL: quality of life
SUS: System Usability Scale

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Remote Monitoring of Physiology in People Living With Dementia: An Observational Cohort Study

Michael C B David, BSc, MBBS; Magdalena Kolanko, BSc, MBBS; Martina Del Giovane, MSc; Helen Lai, MRES; Jessica True, MA; Emily Beat, BSc; Lucia M Li, BSc, MBBS, PhD; Ramin Nilforooshan, MD, PhD; Payam Barnaghi, PhD; Paresh A Malhotra, 1,2, PhD; Helen Rostill, ClinPsy; David Wingfield, DM; Danielle Wilson, BSc; Sarah Daniels, MSc; David J Sharp, PhD; Gregory Scott, PhD

1UK Dementia Research Institute Care Research and Technology Centre, Imperial College London, London, United Kingdom
2Imperial College London, Brain Sciences, South Kensington, London, United Kingdom
3Surrey and Borders Partnership NHS Foundation Trust, Leatherhead, Surrey, United Kingdom

Corresponding Author:
Gregory Scott, PhD
UK Dementia Research Institute Care Research and Technology Centre
Imperial College London
9th Floor, Sir Michael Uren Hub
86 Wood Lane
London, W12 0BZ
United Kingdom
Phone: 44 (0)207 594 9010
Email: gregory.scott99@ic.ac.uk

Abstract

Background: Internet of Things (IoT) technology enables physiological measurements to be recorded at home from people living with dementia and monitored remotely. However, measurements from people with dementia in this context have not been previously studied. We report on the distribution of physiological measurements from 82 people with dementia over approximately 2 years.

Objective: Our objective was to characterize the physiology of people with dementia when measured in the context of their own homes. We also wanted to explore the possible use of an alerts-based system for detecting health deterioration and discuss the potential applications and limitations of this kind of system.

Methods: We performed a longitudinal community-based cohort study of people with dementia using “Minder,” our IoT remote monitoring platform. All people with dementia received a blood pressure machine for systolic and diastolic blood pressure, a pulse oximeter measuring oxygen saturation and heart rate, body weight scales, and a thermometer, and were asked to use each device once a day at any time. Timings, distributions, and abnormalities in measurements were examined, including the rate of significant abnormalities (“alerts”) defined by various standardized criteria. We used our own study criteria for alerts and compared them with the National Early Warning Score 2 criteria.

Results: A total of 82 people with dementia, with a mean age of 80.4 (SD 7.8) years, recorded 147,203 measurements over 958,000 participant-hours. The median percentage of days when any participant took any measurements (ie, any device) was 56.2% (IQR 33.2%-83.7%, range 2.3%-100%). Reassuringly, engagement of people with dementia with the system did not wane with time, reflected in there being no change in the weekly number of measurements with respect to time (1-sample t-test on slopes of linear fit, P=.45). A total of 45% of people with dementia met criteria for hypertension. People with dementia with α-synuclein–related dementia had lower systolic blood pressure; 30% had clinically significant weight loss. Depending on the criteria used, 3.03%-9.46% of measurements generated alerts, at 0.066-0.233 per day per person with dementia. We also report 4 case studies, highlighting the potential benefits and challenges of remote physiological monitoring in people with dementia. These include case studies of people with dementia developing acute infections and one of a person with dementia developing symptomatic bradycardia while taking donepezil.

Conclusions: We present findings from a study of the physiology of people with dementia recorded remotely on a large scale. People with dementia and their carers showed acceptable compliance throughout, supporting the feasibility of the system. Our findings inform the development of technologies, care pathways, and policies for IoT-based remote monitoring. We show how
IoT-based monitoring could improve the management of acute and chronic comorbidities in this clinically vulnerable group. Future randomized trials are required to establish if a system like this has measurable long-term benefits on health and quality of life outcomes.

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**KEYWORDS**
dementia; remote monitoring; physiology; Internet of Things; alerts; monitoring; technology; detection; blood pressure; support; feasibility; system; quality of life

**Introduction**

Dementia engenders a significant burden to patients, carers, and health care services. In the United Kingdom (UK), there are an estimated 850,000 people with dementia, a number expected to rise to over 2 million by 2051 [1]. Dementia care costs the National Health Service approximately £23 (US $27.88) billion per year. There is a pressing need for interventions that reduce the burden on health care services and carers.

In addition to cognitive and behavioral symptoms, dementia is commonly associated with long-term comorbidities, including hypertension, diabetes, malnutrition or unintentional weight loss, and heart disease [2-5]. Many such comorbidities are adverse factors in its progression [2,3,6-10] but are underrecognized and undertreated [11,12]. People with dementia are also at increased risk of hospital admission especially for infections and falls [3,13-15]. People with dementia are more likely to die during admissions, and over a third who go into hospital from home are discharged to a care home [16,17]. Abnormal physiological measurements are more common in people with dementia because of autonomic dysfunction, comorbidities, medication side effects, and acute illnesses [18-21]. People with dementia are also at increased risk of frailty [22]. The interaction between frailty and acute illnesses confers a multiplicative risk for significant morbidity and mortality [23]. A combination of poor premorbid function with atypical presentations and a reduced ability to describe and communicate symptoms drives the increased risk [24]. Recognizing and treating illnesses early leads to better outcomes, especially in the elderly [25].

Using “Internet of Things” (IoT) technology, physiological measurements can be recorded at home and transmitted automatically to caregivers [26]. Such technology can improve the monitoring and treatment of comorbidities and detect developing acute illness [26]. Higher temporal frequency of measurements in a more “naturalistic” setting can potentially provide more accurate, granular data on patients’ health. It also reduces the need for patients with reduced mobility to travel to access care. Therefore, IoT could improve the health and quality of life of people with dementia and reduce the burden on services [26]. Furthermore, by involving people with dementia in their own care, we can maximize empowerment regarding their own health [27]. This is vital for effective ethical care and can be in part enabled through technology [28]. There are also likely benefits to carers who can be involved directly in the ongoing assessments while having increased confidence to leave the people with dementia alone.

There is considerable interest from health and social care policy makers in systems that enable remote monitoring of physiological parameters in community-dwelling people with dementia [29,30], especially given the COVID-19 pandemic [31]. However, in-home monitoring creates new challenges for clinical practice. Guidelines for the frequency of remote measurements (eg, daily, weekly), definitions of clinically significant abnormalities (eg, the threshold heart rate [HR] of clinically relevant tachycardia), and algorithms for best-practice care are not established, unlike in the inpatient setting. The UK-wide National Early Warning Score 2 (NEWS, Table S1 in Multimedia Appendix 1) defines illness severity for hospitalized patients using a score aggregated from 6 physiological domains, where a higher subscore means the parameter is further from normal [32]. However, it is unclear whether NEWS, validated for inpatients, is suitable in the home setting. Also, little is known about the distribution of physiological measurements in people with dementia recorded in the community, which is crucial to establish when designing a system to detect abnormalities.

We are unaware of any published data from long-term studies employing IoT devices for physiological monitoring in the homes of people with dementia.

We have developed an IoT platform, “Minder,” that enables physiological measurements to be recorded at home and monitored remotely [33]. Here, we carried out an analysis of the physiology (HR, systolic blood pressure [SBP] and diastolic blood pressure [DBP], oxygen saturation, and body weight) recorded by a group of people with dementia at home. We report on the effectiveness of our Minder system, designed to detect abnormal measurements (“alerts”) and direct a clinical monitoring team. We also retrospectively applied the NEWS criteria to the data as a comparator. Finally, we present case studies highlighting the potential benefits of remotely monitoring people with dementia.

Our aims are to (1) characterize the physiology of people with dementia in their home setting, (2) test whether our system is sensitive to comorbidities and dementia subtypes, and (3) test how well NEWS-style alerts systems translate to community measurements.

**Methods**

**Study Design, Participants, and Recruitment**

We are conducting an ongoing longitudinal community-based cohort study of people with dementia living at home using Minder, passive infrared sensing, and data analytics to enable remote health care monitoring [33]. Patients with an existing
clinical diagnosis of dementia of any cause were recruited from primary care, adult social care services, and memory clinics across Surrey and Borders Partnership NHS Foundation Trust and Hammersmith and Fulham Partnership. People with dementia were enrolled with an associated “study partner,” defined as “a relative or friend who has known the people with dementia for at least 6 months.” A distinction was not made between “study partner” and “carer”; however, the average number of hours the study partners spent caring for their respective people with dementia was 5.4 (range 1-8) for the 40 study partners for whom we have this data. Full inclusion and exclusion criteria are listed in “Methods” in Multimedia Appendix 2. Owing to the developmental and exploratory nature of the ongoing study, the number of participants was not predetermined by a power calculation. The study is reported according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement (Multimedia Appendix 3), guidelines for reporting observational studies [34].

Ethics Approval
The study was approved by the Health Research Authority’s London-Surrey Borders Research Ethics Committee (19/LO/0102). All people with dementia and study partners provided written informed consent for participation and for their data to be included in publications.

Study Procedures and Physiological Measurements
The study protocol and devices used were based on a previous trial [26]. That trial was co-designed with 20 people with dementia, carers, health care and social workers, and academics, who designed the system to be appropriate for use in people with dementia, in addition to data from an Alzheimer's Society survey on technology-enhanced care. The system was first tested in a laboratory setting and home mock-up scenario before being deployed in participants’ homes.

At baseline, people with dementia and their study partners completed demographics questionnaires and people with dementia completed the Standardized Mini-Mental State Examination (SMMSE). All people with dementia received up to 4 IoT medical devices to record 6 physiological measurements: a blood pressure machine for SBP and DBP, a pulse oximeter measuring oxygen saturation and HR, and body weight scales (provided by iHealth), and a thermometer (provided by Withings), and were asked to use each device once a day at any time. Measurements recorded by each device, annotated with a datetime stamp, were automatically transmitted to a day at any time. Measurements recorded by each device, annotated with a datetime stamp, were automatically transmitted immediately to a centralized secure server.

Study Oversight and Minder Alert Criteria
All people with dementia and study partners provided written informed consent. To oversee the study, a monitoring team was established, operating from 9 AM to 5 PM daily, to respond to clinical or technical alerts. The monitoring team was supervised by a consultant psychiatrist, 2 consultant neurologists, a general practitioner, and an occupational therapist. The team had near real-time access to the physiological measurements via a clinical dashboard, which additionally alerted staff when observations met standardized criteria devised by the study team (Table S2 in Multimedia Appendix 4). For any alert, the monitoring team would follow a predefined flowchart to investigate the abnormality, beginning by attempting to contact the people with dementia or study partner (Figures S1-S4 in Multimedia Appendices 5-8, respectively).

Statistical Analyses
All analyses were performed in MATLAB [35]. Data distributions were assessed for normality. Mean and SD are reported for Gaussian data (as per the Shapiro-Wilk test), whereas median and IQR are used for non-Gaussian data. We calculated descriptive statistics for baseline demographics and SMMSE, and grouped these data by dementia subtype, defined as Alzheimer disease (AD), vascular dementia (VD), and α-synuclein–associated dementias (ASyn), that is, combining participants with Parkinson disease dementia and Lewy body dementia.

We summarized the 24-hour timing of measurements by grouping timestamps into hourly bins. We calculated the overall frequency of recordings by dividing the number of days where a participant took at least 1 complete set (ie, all devices available) of measurements by the number of days of observation; we also counted the days when any measurement was taken. To examine whether the frequency of measurements changed over time, for each participant, we counted the number of measurements per week; fit a linear model to this time series; and, at the group level, tested whether the slopes of these fits were significantly different to zero (1-sample t test).

For subsequent analyses, measurement values were excluded as outliers if values were greater than 4 SD from the mean for that participant. For blood pressure, we calculated the proportion of people with dementia whose mean values met clinical criteria for hypertension (SBP/DBP ≥135/85 mg) [36] or hypotension (SBP/DBP ≤90/60 mm Hg) [37].

We charted the body weight of people with dementia over time, using a sliding window average of 5 values. To identify clinically significant weight loss (or gain) [38] in participants with at least 6 months of data, we identified averaged weights that were >5% different, in either direction, from the most recent value recorded at least 6 months previously.

We refer here to 2 different sets of alert thresholds: our own Minder thresholds and the established NEWS thresholds (Table S1 in Multimedia Appendix 1 and Table S2 in Multimedia Appendix 4). The Minder thresholds were used in real time during the study, to alert the monitoring team, whereas the NEWS thresholds were applied retrospectively to the data for comparison. When applying the subscore thresholds of the NEWS [32] to the data, we first removed any repeat measurements recorded within 60 seconds. For each domain within the NEWS criteria, a normal value is scored 0, but 1-3 when values meet predetermined criteria for abnormality (Table S1 in Multimedia Appendix 1), and these subscores are aggregated into a single NEWS score [32]. For each participant, we calculated the number of individual measurements that triggered Minder alerts and NEWS thresholds of 1+ (less abnormal) and 2+ (more abnormal). We then summarized the overall “burden” of alerts per day per participant.
We used the Spearman rank to test for correlations between physiological summary measures and baseline SMMSE scores and 1-way ANOVA to test for differences between the dementia subtypes (AD, VD, ASyn), with post hoc Tukey tests. Owing to the exploratory nature of the analysis, we did not correct for multiple comparisons.

Case Studies
Four case studies, each based on a snapshot from an individual person with dementia, have been identified. These are included for the purpose of demonstrating the use of this monitoring system for detecting acute clinical events as well as chronic changes in physiological measures over time.

Results

Participant Characteristics, Dementia Subtypes, and Analysis Period
Data from 82 people with dementia were analyzed, with a mean age of 80.4 (SD 7.8, range 60.5-96.4) years at study entry; 36 (44%) were women. Table 1 shows baseline participant characteristics including SMMSE scores (mean 23.0, SD 4.2), grouped by dementia subtypes—AD, VD, and ASyn. The medical history of people with dementia was accessed via their general practitioner (GP) records on enrollment: 1 had type 1 diabetes mellitus and 2 had type 2 diabetes mellitus. Although 18 records stated that they had a diagnosis of essential hypertension, 29 were on at least 1 medication with antihypertensive action (calcium channel blockers, angiotensin-converting enzyme inhibitors, β-blockers, α-blocker, angiotensin receptor blockers, and diuretics). There was a significant difference in age between dementia subtypes (1-way ANOVA $F_{2,79}=5.346, P=.007$), with participants with AD older than those with ASyn (post hoc Tukey test, $P=.004$). There was no difference in baseline SMMSE scores between dementia subtypes ($F_{2,78}=2.324, P=.11$). Recruitment to the study was ongoing throughout, and thus those included commenced the study at different points in the analysis period: April 1, 2019, to March 14, 2022 (1078 days; Figure 1A). The median number of days of observations per patient, defined as the days between the first and last recorded measurement, was 432.5 (IQR 164.9-764.0, range 15.8-1077.1) days, a total of 957,861 participant-hours. A total of 37 participants withdrew from the study during the analysis period, including 5 (6%) who died. The most frequent reason for withdrawal was people with dementia moving to a care home. Full details of the withdrawals are reported in Table S3 in Multimedia Appendix 9. Given the nature of the population in this observational study, it was expected that a significant proportion would withdraw or pass away, as their condition progressed.

Table 1. Baseline participant characteristics, grouped by dementia subtype (N=82).\(^a\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall</th>
<th>Dementia type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AD(^b) (n=68)</td>
<td>VD(^c) (n=5)</td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>80.4 (7.8)</td>
<td>81.5 (7.5)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>36 (44)</td>
<td>33 (49)</td>
</tr>
<tr>
<td>Male</td>
<td>42 (56)</td>
<td>35 (52)</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>White ethnicity, n (%)</td>
<td>77 (94)</td>
<td>61 (90)</td>
</tr>
<tr>
<td>SMMSE(^e) (out of 30), mean (SD)</td>
<td>23.0 (4.2)</td>
<td>22.8 (4.1)</td>
</tr>
<tr>
<td>Education, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to 16</td>
<td>35 (45)</td>
<td>28 (44)</td>
</tr>
<tr>
<td>Up to 18</td>
<td>14 (18)</td>
<td>14 (22)</td>
</tr>
<tr>
<td>Vocational(^f)</td>
<td>8 (10)</td>
<td>5 (8)</td>
</tr>
<tr>
<td>University degree</td>
<td>21 (27)</td>
<td>17 (27)</td>
</tr>
</tbody>
</table>

\(^a\)Data from questionnaires completed by participants on enrolment.
\(^b\)AD: Alzheimer disease.
\(^c\)VD: vascular dementia.
\(^d\)ASyn: α-synuclein–associated disorders (Parkinson disease dementia and Lewy body dementia combine).
\(^e\)SMMSE: Standardized Mini-Mental State Examination.
\(^f\)Where data are incomplete, percentage calculated from available data only. Vocational education refers to higher education course (above the age of 16 years) toward a specific vocation, rather than 16- to 18-year-old schooling or university degree.
Figure 1. Timings and mean values of in-home measurements taken by PwD. (A) Each horizontal line represents a participant, and each dot represents a recording. Rows have been ordered by date of first observation. (B) Count of measurements by each hour of the day, across the cohort. (C) Timing of each participant’s measurements group per hour of the day, expressed as a percentage of that participant’s total measurements. Rows have been ordered by the hour of maximum percentage of most observations (earliest to latest; a different ordering to panel A). (D) Within-participant mean heart rate (beats per minute, n=66 participants); only participants with more than 7 days’ data are included for D-G. The inset histograms show the number of measurements (x-axis) recorded by each participant (y-axis) for the domain. (E) Systolic blood pressure (bp, mm Hg, n=66). Coloring of bars indicate cutoffs for clinical diagnoses of hypertension (≥135 mm Hg, red) and hypotension (≤90 mm Hg, blue). (F) Diastolic blood pressure (bp, mm Hg, n=66). Coloring of bars indicate cutoffs for hypertension (≥85 mm Hg, red) and hypotension (blue, ≤60 mm Hg). (G-I) Mean calculated from all measurements for each individual of body temperature (°C, n=82), oxygen saturation (% , n=40), body weight (kg, n=44). bp: blood pressure; PwD: people with dementia.

Number, Timing, and Frequency of Physiological Measurements

There were 147,203 individual measurements recorded among the 82 participants. Measurements were most often recorded in the morning, with 8-9 AM the most frequent hour (Figure 1B), but there was wide between- and within-participant variability (Figure 1C). We defined participants’ frequency of physiological measurement recording in 2 ways. The median proportion of days of observation during which any participant took at least 1 full set of measurements was 13.9% (IQR 1.2%-33.1%, range 0%-61.0%). The median percentage of days when people with dementia took at least 1 measurement using any device was 56.2% (IQR 33.2%-83.7%, range 2.3%-100%) and did not differ between dementia subtypes ($F_{2,79}=0.944, P=91$). By either definition, there was no correlation between frequency and SMMSE (Spearman $\rho_{P}=0.17$ and $P=0.095$, respectively). We also examined whether measurement frequency changed over the study, that is, that might reflect study fatigue or difficulties with devices. There was no change in the weekly number of measurements in people with dementia with respect to time.
Values of Physiological Measurements and Prevalence of Hypertension

Figure 1D-I shows for each measurement domain the distributions of participants’ mean values recorded during the study for people with dementia with more than 7 days of measurements. Grand means, calculated as the mean of all the within-subject means, were as follows: group mean HR 69.6 (SD 9.4, range 53.5-97.4) bpm, mean SBP 131.7 (SD 14.1, range 85.0-165.9) mm Hg, mean DBP 74.9 (SD 7.5, range 47.7-90.0) mm Hg, median temperature 36.4 (IQR 36.2-36.6, range 36.0-37.2) °C, median oxygen saturation 95.2% (IQR 94.4%-96.5%, range 86.7%-97.5%), median body weight 71.4 (IQR 61.8-83.1, range 48.7-132.0) kg. Using typical clinical criteria [36,37], 45.4% of people with dementia with available data had hypertension (within-subject mean either SBP/DBP ≥135/85 mg), and 1 had hypotension (within-subject mean either SBP/DBP ≤90/60 mm Hg; Figure 1D and E). Figure S5A-F in Multimedia Appendix 10 shows the distributions of within-participant SDs of values.

Physiological Measurements Between Dementia Subtypes

We grouped the within-participant means and SDs by dementia subtypes (Figure 2A-D for SBP/DBP; see Figure S6 in Multimedia Appendix 11 for other domains). There was a significant difference across subtypes in mean SBP (F_{2,63}=6.203, P=.003), SD of DBP (F_{2,63}=3.790, P=.03, post hoc Tukey test results shown in Figure 2), and SD of oxygen saturation (F_{2,37}=6.317, P=.004), with ASyn higher than AD participants (post hoc Tukey test, P=.005) and VD participants (post hoc Tukey test, P=.01).
Body Weight and Prevalence of Clinically Significant Weight Loss

Using the criteria of >5% change over 6 months [38] (Figure 3A), 13 (28%) participants who recorded weight measurements for at least 6 months had at least 1 period of weight loss during the study; 15 (33%) had weight gain. The median percentage change in body weight over the whole study was −1.6% (IQR −3.4% to 1.7%, range −8.4% to 17.6%; Figure 3B). There was no relationship between change in body weight and SMMSE (P=.54).

Figure 3. Body weight over time in PwD. (A) Participants’ body weight over time. Each line represents a different PwD, and each point on the line represents the sliding window average value of 5 body weights. The blue segments indicate values that were >5% less than values 6 months previously, suggesting clinically significant weight loss [38]; the red segments indicate >5% weight gain. (B) Participants’ final body weight (average of 5 measurements) is expressed as a percentage of their baseline weight; bins for >5% weight change are colored blue (loss) and red (gain). PwD: people with dementia.

Physiological Measurements Generating Alerts

To inform the development of remote monitoring services, we calculated the prevalence of abnormalities generating “alerts” according to several criteria.

The prevalence of abnormalities recorded by people with dementia according to NEWS subscore criteria is shown in Figure 4A-D. In-home measurement domains were here treated independently, that is, not combined into a single NEWS score, because people with dementia did not necessarily record measures contemporaneously and because the full NEWS data, that is, respiratory rate and conscious level, were not captured. Instead, alerts could be generated for measurements in a single domain if they crossed either the 1+ or 2+ thresholds.

We retrospectively calculated the burden of alerts that would have been generated using NEWS subscore criteria, that is, the proportion and rate of measurements that exceeded different subscore thresholds (Figure 4). A total of 9.46% of all measurements would generate an alert for meeting the criteria of a NEWS subscore of 1 or more (1+), and 3.03% of measurements using a NEWS subscore of 2+. By comparison, the proportion using our Minder study criteria (Table S2 in Multimedia Appendix 4) was 7.88%. We summarized the alerts per participant per day to indicate the potential overall alert burden (Figure 4). The median frequency of alerts per day per participant was 0.233 (IQR 0.14-0.37; range 0-1.33) using NEWS 1+ and 0.066 (IQR 0.02-0.15; range 0-0.67) using NEWS 2+. Using our Minder criteria, the median frequency was 0.140 (IQR 0.07-0.25; range 0-1.17). There was no relationship between alerts per day, using either NEWS (1+ or 2+) or Minder criteria and SMMSE (P=.56, P=.54, P=.79, respectively) or dementia subtype (P=.92, P=.26, and P=.95).
Figure 4. Frequency of physiological measurement alerts in people with dementia, by NEWS and Minder criteria. For each domain, each line with superimposed circles shows the minimum, maximum, and individual observations for each PwD, after first removing any measure recorded within 60 seconds of another in the same domain. The shaded areas correspond to a NEWS subscore of 1 (yellow), 2 (orange), or 3 (red). The histograms show the distribution of measurements across the group, in relation to the ranges for NEWS subscores, annotated with the percentage of measurements in each range. (A) Heart rate (beats per minute); (B) SBP (mm Hg); (C) temperature (°C); (D) oxygen saturation (%). Data were first filtered by removing any measure recorded within 60 seconds of another in the same domain. Alert for meeting the criteria of a NEWS subscore of 1 or more = NEWS 1+; alert for meeting the criteria of a NEWS subscore of 2 or more = NEWS 2+. (E) Data were labeled by a NEWS subscore of 0 (turquoise), 1+ (yellow), or 2+ (orange). Each horizontal row of circles (left) shows measurements for each participant, colored accordingly. Each subsequent column (left-right) shows the daily number of measurements (turquoise), and then the frequency of alerts using the criteria of NEWS 1+, NEWS 2+, and the Minder platform. (F) Histograms of the alerts per day per participant across the duration of the study, for criteria of NEWS 1+ (top), NEWS 2+ (middle), and the Minder platform (bottom). NEWS: National Early Warning Score 2; PwD: people with dementia; SBP: systolic blood pressure.

Case Studies

Here we report four case studies demonstrating the ability of the monitoring system to detect clinically relevant changes in physiological measurements. This provides evidence for the use of the system in picking up acute illness in a timely manner while also allowing clinicians to monitor chronic changes in individual patients.

1. Change in HR observations after pacemaker insertion: An 83-year-old man with AD was admitted to the hospital after a posterior myocardial infarction, resulting in a long gap in measurements (Figure 5A). After the infarction, he was persistently bradycardic (40-50 bpm) and had a permanent pacemaker fitted. Frequent HR readings of approximately 60 bpm followed the recommencement of home monitoring. Physiological measurement abnormalities leading to urinary tract infection (UTI) diagnosis: An 81-year-old woman with AD had a temperature of 37.9 °C and HR of 102 bpm (Figure 5C). The monitoring team called the carer who relayed symptoms of a UTI. The carer was advised to call 111 (a public service for immediate health advice) and was seen at the hospital. A UTI was subsequently diagnosed, and treatment commenced at home.

2. Symptomatic bradycardia in a person with dementia on donepezil: A 78-year-old man with AD on donepezil recorded a series of low HR measurements over 3 weeks (lowest=44 bpm; Figure 5C), generating alerts for the
monitoring team. The carer told the team that the person with dementia was more fatigued. He was advised to see the GP who switched donepezil, known to cause bradycardia and fatigue, for memantine. Our system showed a resultant increase in HR.

4. Remote physiological monitoring in a person with dementia with COVID-19 infection: An 81-year-old man with AD developed coryzal symptoms, a nonproductive cough, and a temperature of 38.37 °C (Figure 5E). Oxygen saturation remained >95%. Two days later, he was pyrexial again (38.57 °C) and tested positive for COVID-19 at home. The person with dementia was closely monitored with daily check-ins by the monitoring team. Ten days later, he tested negative. The person with dementia lost weight (89 to 85.7 kg after the infection). This was subsequently followed up by the GP.

Figure 5. Case studies highlighting the potential benefits and challenges of remote physiological monitoring in people with dementia. Case studies are labeled according to descriptions in text. HR: heart rate; UTI: urinary tract infection.

Discussion

Study Scale

We have deployed IoT medical devices in the homes of a cohort of people with dementia, providing a rich data set of naturalistic physiological measurements. We believe that this is the first time the physiology of people with dementia has been recorded in this setting at such a scale and sustained period (approximately 150,000 measurements, approximately 1,000,000 participant-hours). We found a system of this nature to be realizable and effective in detecting acute and chronic physiological abnormalities.

Principal Findings

We found that people with dementia recorded a full set of observations on 13.9% of days; however, at least 1 measurement was taken on more than half the study days, on average. Although the data were often incomplete, with measurement in some domains more likely to be recorded than others, there was no decline in compliance over time. Overall, concerns that people with dementia are unlikely to remember or be unwilling to have measurements taken in the community appear misplaced. However, these findings show that serial naturalistic data in people with dementia obtained remotely are likely to be patchy compared with what is possible in a nurse-led inpatient setting. Although there was no correlation between compliance and SMMSE in our data, it is possible that in more advanced dementia, there may be a reduction in compliance. However,
although people with dementia with a lower SMMSE may be less likely to remember to take measurements, they are more likely to have a carer to support measurements.

Our system has provided an opportunity to describe the hitherto poorly understood behavior of physiological measures over extended periods in an older adult, cognitively impaired population, and to consider how physiology relates to comorbidity. On the basis of the data collected in this study, we detected a high prevalence of hypertension, an important factor in dementia development [8,9]. We also detected physiological differences between dementia subtypes, with lower and more variable blood pressure seen in people with dementia with ASyn, in keeping with the known associated autonomic dysfunction [39]. Our case studies provide further evidence that, at the individual level, remote monitoring can detect symptomatic bradycardia, acute infections, and medication side effects.

The relationship between cognitive decline and physical health is complex. For example, regarding blood pressure, both hypo- and hypertension have been implicated in the progression of cognitive decline [40]. Furthermore, because they have been largely excluded from previous randomized trials [41], the value of treating hypertension in older adult, cognitively impaired patients is not established. Body weight, as a marker of nutritional status, also has an important but complex interaction with dementia. We did not find an association with SMMSE, but it is likely that a longer time course would be required to detect one.

IoT-based platforms like Minder represent a new paradigm for clinical measurement, that is, large-scale, long-term, sporadic, patient-initiated, and remotely recorded. Definitions and care pathways for significant abnormalities in this context are not well established. These are important differences versus the established settings of primary care (infrequent, supervised, in-person measurements), secondary care (high-frequency in-person multimodal monitoring of acutely unwell patients), and ambulatory monitoring (devices worn continuously for several days). When we applied the NEWS criteria, validated for hospital use, we found that the median rate of alerts generated was 0.066 or 0.233 per day per participant, depending on the threshold used, which spanned the rate (0.114) from our own criteria. These findings provide an indication of the potential workload that would be placed on remote monitoring service (approximately 100 alerts per day per 1000 patients). There is, however, potential to improve the clinical use of such alerts, for example, by using personalization, whereby thresholds are set according to patients’ own historical data and constantly updated in response to their measurements.

**Future Directions**

Our study highlights the benefits and risks of remote monitoring systems. With such systems, there is the potential to detect developing acute illness, facilitating early intervention, improving outcomes, and avoiding hospital admission [42,43]. Remote physiological monitoring of this kind could identify trends over weeks to months, relating to, for example, comorbidities like hypertension, malnutrition, and drug side effects. Both timescales are pertinent in people with dementia who, less able to recognize and communicate when they become acutely unwell, are more likely to develop comorbidities.

We are currently scaling up the size of the cohort in the study to 200 people with dementia in the form described here. There are further plans to provide a cut-down version of the system to a cohort of 1000. A key part of the ongoing work is ascertaining, which features are most informative, in order to design a system that is scalable.

It remains to be established the measurable benefit a system like this can have on long-term health outcomes and quality of life. A previous randomized trial did not point toward benefit, but this may well be due to a piecemeal approach [44]. In fact, successful implementation will depend on systematic work understanding how best to use technology in the home.

**Limitations**

We have identified the following limitations to our IoT system and to the analysis presented. First, we were limited in our ability to reliably characterize and record every change in patients’ medical status and medication over the course of the study. This has implications for interpretation of the physiological findings. The association between changes in physiological observations and medication may be addressed using data linkage with the patient electronic clinical record—something we are exploring as the study develops. Second, we did not have a control group of age-matched healthy participants to provide comparisons for measurement compliance and physiological values. The normative values are for vital signs are well established, but not necessarily in the context of elderly people, in their own homes. Third, our analysis of compliance was limited as we could not discern which recordings were initiated by people with dementia versus in response to contact by the monitoring team. We therefore have likely overestimated the frequency with which people with dementia recorded measurements. However, the value in allowing people with dementia to record their vital signs remotely withstands, even if they have had to be prompted.

Fourth, our alert rates are instead likely to be underestimates, because we excluded extreme outliers and duplicate values and did not evaluate abnormalities relating to DBP or body weight.

**Conclusions**

There is growing interest in establishing remote monitoring within care services, amplified by the COVID-19 pandemic and calls for “hospital and home” initiatives [29,30]. We believe that remote monitoring technology can be transformative for the health and social care of people with dementia. Future research must demonstrate the clinical use of remote monitoring and address how such technologies are best integrated with existing care. Together, our findings inform the development of technologies, pathways, and policies for remote monitoring of people with dementia.
Acknowledgments
We thank the patients and study partners who took part in the study. We also thank all members of the UK Dementia Research Institute Care Research & Technology Centre who contributed in some way to this work. A full list of members can be found in Multimedia Appendix 12. This work was funded by UK Dementia Research Institute award. Surrey and Borders partnership is the sponsor of this study.

Data Availability
The data collected during the current study are available from the corresponding author on reasonable request. The institute intends to store data in a public repository on dementiasplatform.uk in due course.

Authors’ Contributions
JT, RN, PB, HR, D Wilson, DJS, and GS designed the study. HL, JT, EB, RN, PB, D Wingfield, and SD collected the data. MCBD, MK, MDG, HL, and GS analyzed the data. MCBD, MDG, LML, RN, D Wingfield, PAM, DJS, and GS prepared the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Threshold values for abnormal measurements in the National Early Warning System 2.
[DOCX File, 17 KB - aging_v61e43777_app1.docx]

Multimedia Appendix 2
Methods: inclusion and exclusion criteria of study partners.
[DOCX File, 15 KB - aging_v61e43777_app2.docx]

Multimedia Appendix 3
STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist.
[DOCX File, 33 KB - aging_v61e43777_app3.docx]

Multimedia Appendix 4
Threshold values for abnormal measurements defined in the Minder platform.
[DOCX File, 13 KB - aging_v61e43777_app4.docx]

Multimedia Appendix 5
Within-participant standard deviation for all six measurement domains; only participants with more than 7 days data are included. PwD: people with dementia.
[PNG File, 312 KB - aging_v61e43777_app5.png]

Multimedia Appendix 6 [PNG File, 287 KB - aging_v61e43777_app6.png]

Multimedia Appendix 7
Flowchart followed by monitoring team in response to alerts for abnormal oxygen saturation. GP: General physician.
[PNG File, 154 KB - aging_v61e43777_app7.png]

Multimedia Appendix 8
Flowchart followed by monitoring team in response to alerts for body temperature. GP: general physician; UTI: urinary tract infection.
[PNG File, 166 KB - aging_v61e43777_app8.png]

Multimedia Appendix 9
Participant withdrawals.
[DOCX File, 13 KB - aging_v61e43777_app9.docx]

Multimedia Appendix 10
Flowchart followed by monitoring team in response to alerts for abnormal heart rate. CMT: clinical monitoring team.

Multimedia Appendix 11
Flowchart followed by monitoring team in response to alerts for abnormal blood pressure readings. BP: blood pressure; GP: general physician.

Multimedia Appendix 12
References


29. Martin M. The role of remote monitoring in the future of the NHSX. NHSX. 2020. URL: https://tinyurl.com/2au4p2bk [accessed 2023-02-06]


**Abbreviations**

AD: Alzheimer disease  
ASyn: α-synuclein–associated dementias  
DBP: diastolic blood pressure  
HR: heart rate  
IoT: Internet of Things  
NEWS: National Early Warning Score  
SBP: systolic blood pressure  
SMMSE: Standardized Mini-Mental State Examination  
UTI: urinary tract infection  
VD: vascular dementia
Factors Influencing Continued Wearable Device Use in Older Adult Populations: Quantitative Study

Karla Muñoz Esquivel1,2*, PhD; James Gillespie2*, BEng; Daniel Kelly2, PhD; Joan Condell2, PhD; Richard Davies2, BEng; Catherine McHugh2, PhD; William Duffy2, PhD; Elina Nevala3, MSc; Antti Alamäki3, MSc; Juha Jalovaara1, BSc; Salvatore Tedesco4, PhD; John Barton4, MEng; Suzanne Timmons5, MBChB, MD; Anna Nordström6, MD, PhD

1Department of Computer Science, Atlantic Technological University, Letterkenny, Ireland
2Faculty of Computing, Engineering, and the Built Environment, Ulster University, Derry, United Kingdom
3Department of Physiotherapy, Karelia University of Applied Sciences, Karelia, Finland
4Wireless Sensors Network Group, Tyndall National Institute, University College Cork, Cork, Ireland
5Centre for Gerontology and Rehabilitation, School of Medicine, University College Cork, Cork, Ireland
6Department of Public Health and Clinical Medicine, Umeå University, Umeå, Sweden
* these authors contributed equally

Corresponding Author:
Karla Muñoz Esquivel, PhD
Department of Computer Science
Atlantic Technological University
Port Road
Letterkenny, F92 FC93
Ireland
Phone: 353 74 918 6000
Email: karla.munozesquivel@atu.ie

Abstract

Background: The increased use of wearable sensor technology has highlighted the potential for remote telehealth services such as rehabilitation. Telehealth services incorporating wearable sensors are most likely to appeal to the older adult population in remote and rural areas, who may struggle with long commutes to clinics. However, the usability of such systems often discourages patients from adopting these services.

Objective: This study aimed to understand the usability factors that most influence whether an older adult will decide to continue using a wearable device.

Methods: Older adults across 4 different regions (Northern Ireland, Ireland, Sweden, and Finland) wore an activity tracker for 7 days under a free-living environment protocol. In total, 4 surveys were administered, and biometrics were measured by the researchers before the trial began. At the end of the trial period, the researchers administered 2 further surveys to gain insights into the perceived usability of the wearable device. These were the standardized System Usability Scale (SUS) and a custom usability questionnaire designed by the research team. Statistical analyses were performed to identify the key factors that affect participants’ intention to continue using the wearable device in the future. Machine learning classifiers were used to provide an early prediction of the intention to continue using the wearable device.

Results: The study was conducted with older adult volunteers (N=65; mean age 70.52, SD 5.65 years) wearing a Xiaomi Mi Band 3 activity tracker for 7 days in a free-living environment. The results from the SUS survey showed no notable difference in perceived system usability regardless of region, sex, or age, eliminating the notion that usability perception differs based on geographical location, sex, or deviation in participants’ age. There was also no statistically significant difference in SUS score between participants who had previously owned a wearable device and those who wore 1 or 2 devices during the trial. The bespoke usability questionnaire determined that the 2 most important factors that influenced an intention to continue device use in an older adult cohort were device comfort (τ=0.34) and whether the device was fit for purpose (τ=0.34). A computational model providing an early identifier of intention to continue device use was developed using these 2 features. Random forest classifiers were shown to provide the highest predictive performance (80% accuracy). After including the top 8 ranked questions from the bespoke questionnaire as features of our model, the accuracy increased to 88%.
Conclusions: This study concludes that comfort and accuracy are the 2 main influencing factors in sustaining wearable device use. This study suggests that the reported factors influencing usability are transferable to other wearable sensor systems. Future work will aim to test this hypothesis using the same methodology on a cohort using other wearable technologies.

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KEYWORDS
usability; older adults; remote sensing; sensor systems; wearable device; mobile phone

Introduction

Background
Advancements in health care have resulted in increases in life expectancy. As a consequence, a growing proportion of the population are older adults [1]. This aging population, accompanied by an increasing number of older adults becoming physically inactive [2], is placing an additional burden on health care systems and directing research toward early detection or prevention of future medical issues. Remote rehabilitation and monitoring provide an opportunity to reduce demands on health care systems and the inevitable costs associated with providing care for an aging population [3]. Remote rehabilitation can allow for access to health-based resources such as nurses, health practitioners, and specialists through technology while avoiding associated costs such as travel [4]—from both a monetary and environmental perspective. Some technology solutions have been adapted for remote rehabilitation over the last decade. Synchronous videoconferencing, for example, is one of the most commonly used technologies to deliver rehabilitation therapy to clients who are in a different location from their therapist [5]. Wearable sensor systems have recently been used to provide insights into physical activity, physical function, and general health, and as a result, therapists and clinicians can provide more detailed insights into a patient’s health and progress on a remote basis. At present, most research on wearable sensor technology is developed with accuracy at the center of the study design. This often comes at the expense of usability [6] even though research studies have indicated that perceived ease of use is just as important as perceived usefulness when it comes to technology acceptance [7]. Indeed, Mancini and Horak [8] note that, to achieve successful adoption of remote rehabilitation technologies, the solution must be both practical and usable, which is of particular importance when considering wearable sensor systems.

The Smart Sensor Devices for Rehabilitation and Connected Health project focuses on monitoring the physical capacity of older adults. The project evaluated wireless sensor systems and their capabilities for remote rehabilitation with a particular focus on end-user acceptance. The ultimate goals of technology-assisted personal health management are both continued long-term use of the device and improved well-being [9]. This study specifically focused on understanding the factors influencing continued long-term use.

Understanding the factors that influence continued device use is important as this will inform future wearable device design, ensuring that adoption and the impact of that adoption has the highest possible chance of success. This will, in turn, allow for the successful rollout of telehealth services in the future, such as remote rehabilitation, and overall increase the likelihood of improved well-being.

Related Work
Previous work has already shown that, for monitoring technology to be accepted by older adults, it must be easy to use and not impair mobility and independence [10]. Research has also shown that human factors such as portability and resilience are the main factors that influence continued device use [11].

Older adults are interested in smart wearable devices that offer functionality for daily living and are more likely to consider using one if compatible [12]; thus, device selection is important [13]. The user’s attributes and device features are the main characteristics to observe when evaluating wearable devices [14]. Environmental and individual features need to be considered when deciding on a sensor technology device; in particular, a device that is user focused would be valuable [15]. A wearable device offering user-friendly features for everyday tasks is more appealing to individuals as they trust the information provided. If an individual trusts the device, there is an increased chance of continued use [14]. A positive finding from previous research related to older adults using activity monitoring technology showed that older adults did not struggle to use new technology [16].

The literature shows that usability challenges must be addressed to increase the likelihood of continued device use. Therefore, technology must be designed and implemented such that it is practical, unobtrusive, and well-received by older adults and, ultimately, promotes health benefits.

Balance is one of the critical characteristics used to assess the functional capacity of older adults in the literature. However, despite the growing number of articles supporting the use of balance assessment technology, there are still substantial gaps in the full understanding of the technology. In particular, existing literature in the area does not consider factors that may affect the continued long-term use of wearable technology in real-world conditions. A previous study examined the real-world use of multiple wearable sensors, noting that participants found wrist-worn sensors to be the most favorable as they were adaptable and user-friendly [15]. Core areas to focus on are preferred features of the wearable device and possible issues arising from older adults operating the device [17]. Longitudinal studies have also been suggested as an approach when assessing the usability of wearable sensors to ascertain whether ratings change with extended device use and user experience [14].

There are limited quantitative studies on long-term device usability to observe the associated influencing factors [18].
feedback is key to understanding participants’ experience in a study and is necessary for determining whether older adults will continue to use wearable technology [19]. A previous study focused on individual preferences and asked participants to share their experiences using a fitness device; the main issues were remembering to wear the device, lack of comfort when wearing it, limited sharing support to determine a baseline with others, and inaccurate data recorded during activities [20].

We conducted a study aimed to better understand the usability factors that most influence whether an older adult will decide to continue to use a wearable device. We hypothesized that initial perceptions related to human factors of a wearable sensor system can be used as a predictor of continued device use in the future. To test this hypothesis, a study was designed to analyze data related to older adults’ perceptions of wearable activity trackers after 7 days of use. Data were collected related to participant perceptions of wearable device human factors as well as measurements of participant functional status, health status, and wearable device activity tracker measurements from a cohort of 65 older adults aged ≥65 years. One of the objectives of the research was to assess what specific factors may affect participants’ intention to continue using the wearable device beyond the 7-day study period. There are three key methodologies that could be used for usability assessment: (1) inspection involving expert observation (eg, heuristic evaluation), (2) inquiry involving qualitative data collection (eg, surveys), and (3) testing involving quantitative data collection in a real environment (eg, remote usability testing) [13]. The methodology used in this study applies both inquiry and testing methods based on a bespoke usability questionnaire completed by participants after the 7-day study period during which they used a Xiaomi Mi Band 3.

Methods

Overview

This section will cover the protocol used during the data collection process and describe each of the questions asked and how they relate to measuring usability. Detailed information will also be provided for the participant cohort and the hardware used to capture their activity data. This section establishes the methods used to process and analyze the data and, finally, predict continued device use.

Protocol

This was a retrospective case series–based study. A series of older adults aged ≥65 years were given a wearable device and observed over a 1-week period. The usability data of the wearable device were then characterized among the participant series.

The study was based on a free-living data collection protocol conducted over a 7-day period. A free-living data collection protocol is a common method of collecting data from participants, particularly in sensor-based studies. The free-living aspect indicates that data are collected from a participant’s normal everyday living environment, typically over a period of ≥24 hours. This approach aims to eliminate any social, behavioral, and environmental biases that would otherwise be present in other testing or simulated environments.

Participants for this study were recruited from 4 different countries within the Northern Periphery and Arctic regions of Europe. These were namely Northern Ireland, Ireland, Finland, and Sweden. Inclusion criteria required participants to be aged ≥65 years, have the physical capacity to walk 20 m without the assistance of another person, and be cognitively able to answer questionnaires.

Participants met the researchers performing the trial in person twice—one at the start of the trial and again 7 days later at the end of the trial. In the first meeting, the researchers took body measurements (height, weight, and grip strength for both hands), trained the participants in device use using a standardized training manual, and asked them to complete 4 health-related questionnaires. Participants were then asked to complete two physical function tests: (1) the Five-Time Sit-to-Stand test (STS5) and (2) two 10-m walk tests. For the STS5 test, the total time to complete 5 repetitions of going from a seated position to a standing position was recorded. For the 10-m walk test, the time to complete each of the two 10-m walks was recorded (WT10M1 and WT10M2) as well as the number of steps taken in each walk (WS10M1 and WS10M2).

A date for the second meeting was agreed upon, and participants were given the wearable device to wear and bring home with them. At the second meeting, the participants met with the researcher and returned the wearable device. The participants were then asked to complete 2 posttrial questionnaires focusing on usability and human factors. Figure 1 provides an overview of the study process. Ethics approval for the research study was granted at each of the 4 test sites (Ulster University, United Kingdom; Tyndall National Institute, University College Cork, Ireland; Umeå University, Sweden; and Karelia University of Applied Sciences, Finland).

The standard tests (eg, sit-to-stand and timed walk) and measures that were carried out as part of this study were used to assess the physical health of the participants. Although this study focused on usability and intention to continue using the device, data from the standard tests are part of a larger study, and further data analyses will be performed for potential future publication.
Questionnaires

The trial used 6 questionnaires to collect various data from the participants. A total of 4 questionnaires were administered before the trial began, and 2 were administered after trial completion. The four Pretrial Questionnaires were as follows: (1) the 36-item Short Form Health Survey (SF-36) [21], a set of generic, coherent, and easily administered quality-of-life measures; (2) the Mini-Mental State Examination (MMSE) [22], a set of questions used to assess a patient’s cognitive impairment; (3) the Geriatric Depression Scale (GDS) [23], used to assess depressive symptomatology in older adults; and (4) the Mobile Device Proficiency Questionnaire (MDPQ) [24], used to accurately assess the mobile device proficiency of older adults. Each questionnaire was administered using an interview-based approach where the researcher asked the participants each question and indicated the possible answers they could give. The participants provided a verbal answer to each question, and the researcher recorded the results on paper and, subsequently, electronically. The questionnaires at the first meeting were administered in the following order: (1) SF-36, (2) MMSE, (3) GDS, and (4) MDPQ.

The SF-36 questionnaire was used to understand the participants’ general health status. The MMSE and GDS questionnaires were used to understand the mental health status of the participants. A score of <25 on the MMSE indicates some degree of dementia, whereas a score of >4 on the GDS indicates some degree of depression. The data were used to characterize the overall health of the participant group and understand the relative health of the participants compared with the general population. The MDPQ was used to estimate their level of familiarity and experience using technology and whether this was linked to continued device use afterward. Questionnaire scores and statistics are discussed in the Results section.

The two Posttrial Questionnaires were as follows: (1) the System Usability Scale (SUS) [25], used as a standardized method to evaluate the usability of wearable devices and facilitate benchmarking with other studies, and (2) the usability questionnaire, a bespoke questionnaire designed by the research team to specifically understand older adults’ opinions on wearable sensor technology (Multimedia Appendix 1). This usability questionnaire gathered user opinions on perceived usefulness, comfort, and ease of use as previous research studies have indicated that these are the crucial factors that influence the usability of a wearable device and can ultimately affect the likelihood of continued long-term use [26-28]. Each of these questionnaires was administered using an interview-based approach following the same methodology as the pretrial meeting. The participants were first administered the SUS questionnaire, followed by the bespoke usability questionnaire.

The SUS is a standardized and validated short 10-question survey to help validate the usability of a piece of hardware, software, or wearable device. However, to better understand the participants’ specific opinions of the wearable device usability, a bespoke usability questionnaire was designed, entitled “Accuracy, feasibility and acceptability of wireless monitoring in older people.” The questionnaire first collected dichotomous data on the participants’ familiarity with wearable devices and whether they liked the appearance. Then, a series of questions related to usability, accuracy, and acceptability were asked using an ordinal 5-category scale ranging from strongly agree to strongly disagree. The questionnaire ended with 4 general questions that gathered data on length of time worn and use at night. The final and most important question regarding this study asked the participants if they would continue to use the device after the trial had finished. Responses to this final question were analyzed to gain further insights into what factors influence the intention to continue using the device.

The bespoke usability questionnaire was designed as part of the European Union Interreg Northern Periphery and Arctic Smart Sensor Devices for Rehabilitation and Connected Health project. Experts on this project—who were from clinical, physiotherapy, and technological backgrounds in Sweden, Finland, Ireland, and Northern Ireland—worked together in a workshop meeting that was held in May 2019 in Derry/Londonderry to propose, agree, and finalize a set of questions appropriate to assess the different human factors associated with the wearable sensor system. The bespoke questionnaire was applied for the first time in this study.

Hardware and Software

Each participant in the study was provided with a Xiaomi Mi Band 3 activity tracker, which was secured on the wrist of their nondominant hand. In addition, the participant was provided with a Huawei Y6 smartphone to facilitate interaction with the activity tracker software. Anonymous Google accounts were
created to capture the activity data from each participant. Approximately half (37/65, 57%) of the participants were also requested to wear an Axivity AX3 wrist-worn accelerometer on their dominant hand. The initial plan was to have all participants wear 2 trackers as the raw data collection capabilities of the Axivity AX3 would have facilitated benchmarking between potentially new algorithms and the Xiaomi Mi Band 3. However, an initial feasibility study conducted in Finland on a small number of participants used the bespoke usability questionnaire to conclude that, generally, participants reported usability issues because of wearing 2 trackers. To help keep this from becoming an issue, it was decided to only allow half of the participants to wear 2 trackers. The distribution of those wearing 2 trackers versus 1 was approximately 50% across all the sites (Sweden: 9/20, 45%; Finland: 13/23, 57%; Northern Ireland: 7/14, 50%; Ireland: 8/8, 100%) except for the 100% (8/8) of participants at the site in Ireland who wore 2 trackers. Unfortunately, because of the unexpected impact of COVID-19 in March 2020, the trial in Ireland was interrupted midway, which resulted in 40% (8/20) of the participants receiving 2 trackers and the remaining 60% (12/20) of the participants being unable to take part.

Cohort Description
In total, 65 participants from the 4 locations took part in the study. The mean age of the participants was 70.52 (SD 5.65) years. The mean height of the population was 169.43 (SD 9.05) cm, and the mean weight was 73.45 (SD 13.09) kg. The cohort comprised 57% (37/65) women and 43% (28/65) men. A total of 91% (59/65) of the participants were right-handed, and 9% (6/65) were left-handed. The participants were recruited using leaflets and posters. Recruitment sought older adult volunteers wanting to experience the use of wearable technology such as activity trackers in their daily lives. They should be physically able to walk 20 m unaided and cognitively able to answer questionnaires. The participants were to have no underlying health conditions other than frailty. Targeted recruitment focused on recruiting participants in community centers focusing on older adults (Eglinton Community Centre, Old Library Trust Healthy Living Centre, and U3A Foyle, all in Northern Ireland) and clinics (in Ireland, Sweden, and Finland).

Data Processing, Analysis, and Classification

Overview
An analysis was performed on the collected data to understand the usability factors that most influence whether an older adult will decide to continue using a wearable device. The analysis was divided into four main areas: (1) cohort characteristic analysis, (2) SUS analysis, (3) bespoke usability questionnaire analysis, and (4) predictive modeling. The following sections describe the methods used for each of these areas.

Cohort Characteristic Analysis
Statistical analysis of participants’ demographics, health status, and selected usability results was performed to provide information on the characteristics of the cohort being analyzed in further sections. The cohort of 65 people comprised volunteers from Northern Ireland (n=14, 22%), the Republic of Ireland (n=8, 12%), Finland (n=23, 35%), and Sweden (n=20, 31%). For each participant, a set of 69 features were recorded. The features comprised body metrics, functional test measures, wearable device data, and questionnaire results.

Analysis of the data was performed using SPSS (version 26; IBM Corp) and the Spyder Python integrated development environment (version 5.1.5). Statistical analyses were performed using the Kendall τb, Pearson, or Spearman correlations where appropriate. The analysis also involved computing features such as the mean, variance, and SDs as well as exploring frequencies, histograms, distributions, and statistical tests.

SUS Analysis
Participants were asked to answer the SUS questionnaire to evaluate the Xiaomi Mi Band 3 activity tracker after an average device use of 7.12 (SD 1.53) days. Only the usability of the wearable device was to be considered by the participants.

SUS scores were analyzed to investigate whether geographical location, sex, number of wearables used, or age affected the usability rating. For our analysis, the participants who took part in the trial from Northern Ireland and the Republic of Ireland were grouped into 1 cohort comprising 22 participants because of the relatively small sample size (8/65, 12%) available for the Republic of Ireland and because of their geographical proximity, encompassing the island of Ireland. For the age analysis, we created 3 bins (<70 years, between 70 and 74 years, and >74 years) and categorized the participants accordingly.

The analysis of the SUS data aimed to understand whether geographic location, age, sex, or number of devices worn had an influence on the perceived usability of the device.

Bespoke Usability Questionnaire Analysis
Analysis of data from the bespoke questionnaire focused on understanding responses to question 21: “Would you continue to use the device and app again after the trial is finished?” Various analyses were performed on this question to gain insights into what factors influence continued device use.

Analysis of the statistical distributions of participants from the 2 groups (participants who indicated that they would continue using the device and participants who indicated that they would not continue using the device) was carried out. Independent 2-tailed t tests were carried out on SUS scores for the 2 groups. In addition, correlations between question 21 and all other questions from the bespoke questionnaire were carried out using the Kendall τb rank to identify specific factors that are linked to the intention to continue using the device.

Predictive Modeling
A predictive model is frequently used in statistics and machine learning techniques to model the current data and predict future outcomes. For this part of the analysis, we evaluated models that may predict the intention to continue using a device after the monitoring period. These predictions were based on the usability questionnaire, where the answer to question 21 was predicted based on the answers to the other questions.

An important criterion for wearable technologies is user acceptance. This increases the likelihood that individuals will continue to use the device long-term and beyond periods when
they are being actively monitored. Factors potentially influencing a user’s acceptance of a wearable device include comfort, simplicity, and device intrusiveness. For example, if a device requires frequent interaction, then it could become too much of a burden.

Ethics Approval

Approval for the research study was obtained from each of the participating institutions where required. The Ulster University Research Governance Ethics Committee granted approval under reference REC/19/0026; the University College Cork Clinical Research Ethics Committee of the Cork Teaching Hospitals granted approval under reference ECM 4(a) 16/10/19; and the Regional Research Ethical Review Board of Umeå University, Sweden, granted approval under reference 07-031M with extensions. At the Karelia University of Applied Sciences, Finland, no ethics approval from an institutional review board was required as the research adhered to the ethical principles of research with human participants as per the Finnish National Board on Research Integrity TENK guidelines [29]. The research was conducted in accordance with the principles of the Declaration of Helsinki and in accordance with local statutory requirements. All participants provided written informed consent to take part in this study. Consent was provided for publication by all participants under the condition that the data were anonymized.

Results

Pretrial Questionnaire Results

Summary statistics for each of the 4 health questionnaires (SF-36, MMSE, GDS, and MDPQ) are presented in Table 1, with the general health variable selected to represent the SF-36 questionnaire and the overall MDPQ variable selected to represent the MDPQ questionnaire.

Table 1. Pretrial questionnaire results.

<table>
<thead>
<tr>
<th></th>
<th>Values, mean (SD)</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF-36(^a) general health</td>
<td>72.54 (18.96)</td>
<td>359.471</td>
</tr>
<tr>
<td>MMSE(^b)</td>
<td>28.49 (1.55)</td>
<td>2.410</td>
</tr>
<tr>
<td>GDS(^c)</td>
<td>1.43 (2.11)</td>
<td>4.468</td>
</tr>
<tr>
<td>MDPQ(^d) overall</td>
<td>3.53 (1.26)</td>
<td>1.577</td>
</tr>
</tbody>
</table>

\(^a\)SF-36: 36-item Short Form Health Survey.
\(^b\)MMSE: Mini-Mental State Examination.
\(^c\)GDS: Geriatric Depression Scale.
\(^d\)MDPQ: Mobile Device Proficiency Questionnaire.

Results show that the cohort comprised participants who were, on average, in good health as defined by SF-36 results (mean 72.54 out of 100, SD 18.96). Results showed that only 9% (6/65) of the participants scored <50 on the SF-36 general health component, implying that a small number of participants in the study perceived that they were struggling with health issues. The average MMSE value among all participants was 28.49 (SD 1.55). As previously stated, a score of <25 on the MMSE indicates some degree of dementia, whereas a score of >4 in the GDS indicates some degree of depression. Only 2% (1/65) of the participants scored <25 on the MMSE, with a score of 24. The average GDS score among all participants was 1.43 (SD 2.11), with only 9% (6/65) of the participants reporting scores of >4 in the GDS. The average MDPQ value was 3.53 (SD 1.26), which is between 3 (“not very easily”) and 4 (“somewhat easily”), indicating that our participants were between states when it comes to overall mobile phone device proficiency.

Table 2 shows the relevant background characteristics of all cohorts by region. The table includes summary statistics for age, sex, height, weight, SUS score, and bespoke usability questionnaire—questions 10 (The activity tracker was comfortable to wear at night), 17 (Using the activity tracker helped me be more active), and 21 (Would you continue to use the device and app again after the trial is finished?) and the 3 functional test scores (WT10M1, WT10M2, and STS5). The 3 usability questions are presented as device comfort and becoming more active were identified as the top 2 influencing factors for continuing to use the device. In total, 3 physical function measures were chosen: the two 10-m walking tests and the STS5 as these are deemed important measures when wearing an activity tracker.
Table 2. Summary of background characteristics of the participants (N=65).

<table>
<thead>
<tr>
<th>Background characteristic and cohort or subcategory</th>
<th>Participants, n (%)</th>
<th>Values, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>70.5 (5.65)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>71.1 (5.98)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>70.4 (7.69)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>70.0 (0)</td>
</tr>
<tr>
<td><strong>Sex (female)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole group</td>
<td>37 (57)</td>
<td>N/A a</td>
</tr>
<tr>
<td>Finland</td>
<td>13 (20)</td>
<td>N/A</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>14 (22)</td>
<td>N/A</td>
</tr>
<tr>
<td>Sweden</td>
<td>10 (15)</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Sex (male)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole group</td>
<td>28 (43)</td>
<td>N/A</td>
</tr>
<tr>
<td>Finland</td>
<td>10 (15)</td>
<td>N/A</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>8 (12)</td>
<td>N/A</td>
</tr>
<tr>
<td>Sweden</td>
<td>10 (15)</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>166.9 (22.88)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>168.9 (8.18)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>158.7 (36.42)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>173.5 (9.53)</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>72.3 (15.95)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>69.7 (12.55)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>72.2 (20.51)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>75.5 (13.81)</td>
</tr>
<tr>
<td><strong>SUS b score</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>65 (100)</td>
<td>67.2 (18.27)</td>
</tr>
<tr>
<td>Not acceptable (0≤SUS&lt;50)</td>
<td>12 (18)</td>
<td>40.0 (6.99)</td>
</tr>
<tr>
<td>Marginal (50≤SUS&lt;70)</td>
<td>20 (31)</td>
<td>59.5 (6.57)</td>
</tr>
<tr>
<td>Acceptable (70≤SUS≤100)</td>
<td>33 (51)</td>
<td>81.7 (9.74)</td>
</tr>
<tr>
<td><strong>Question 10</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>4.1 (0.92)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>3.8 (0.98)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>4.4 (0.73)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>4.2 (0.99)</td>
</tr>
<tr>
<td><strong>Question 17</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>3.4 (1.17)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>3.4 (1.08)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>3.8 (1.01)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>3.1 (1.34)</td>
</tr>
<tr>
<td><strong>Question 21 (no)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background characteristic and cohort or subcategory</td>
<td>Participants, n (%)</td>
<td>Values, mean (SD)</td>
</tr>
<tr>
<td>---------------------------------------------------</td>
<td>---------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Whole group</td>
<td>23 (35)</td>
<td>N/A</td>
</tr>
<tr>
<td>Finland</td>
<td>11 (17)</td>
<td>N/A</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>4 (6)</td>
<td>N/A</td>
</tr>
<tr>
<td>Sweden</td>
<td>8 (12)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Question 21 (yes)**

<table>
<thead>
<tr>
<th></th>
<th>Participants, n (%)</th>
<th>Values, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group</td>
<td>42 (65)</td>
<td>N/A</td>
</tr>
<tr>
<td>Finland</td>
<td>12 (18)</td>
<td>N/A</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>18 (28)</td>
<td>N/A</td>
</tr>
<tr>
<td>Sweden</td>
<td>12 (18)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**WT10M1\(^c\)** (seconds)

<table>
<thead>
<tr>
<th></th>
<th>Participants, n (%)</th>
<th>Values, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>8.0 (1.70)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>8.3 (1.07)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>8.3 (2.52)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>7.3 (0.81)</td>
</tr>
</tbody>
</table>

**WT10M2\(^d\)** (seconds)

<table>
<thead>
<tr>
<th></th>
<th>Participants, n (%)</th>
<th>Values, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>7.7 (1.40)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>7.8 (1.01)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>8.3 (1.94)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>7.1 (0.73)</td>
</tr>
</tbody>
</table>

**STS5\(^e\)** (seconds)

<table>
<thead>
<tr>
<th></th>
<th>Participants, n (%)</th>
<th>Values, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole group</td>
<td>65 (100)</td>
<td>11.6 (6.55)</td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>11.0 (1.92)</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>12.8 (10.90)</td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>10.8 (2.41)</td>
</tr>
</tbody>
</table>

\(a\) N/A: not applicable.
\(b\) SUS: System Usability Scale.
\(c\) WT10M1: 10-m walk test time 1.
\(d\) WT10M2: 10-m walk test time 2.
\(e\) STS5: Five-Time Sit-to-Stand test.

**SUS Results**

**Overview**

The results of the SUS questionnaire showed that the average SUS score (N=65) was 67.15 (SD 18.27). Table 3 shows the mean SUS scores for the region, sex, age, and number of wearables used.
Table 3. Summary of statistics of the participants (N=65).

<table>
<thead>
<tr>
<th>Statistic description</th>
<th>Participants, n (%)</th>
<th>SUS(^a) score, mean (SD)</th>
<th>t test (df)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Region</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>23 (35)</td>
<td>68.3 (11.95)</td>
<td>0.091 (2)</td>
<td>.91</td>
</tr>
<tr>
<td>Northern Ireland and Ireland</td>
<td>22 (34)</td>
<td>65.9 (19.34)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>20 (31)</td>
<td>67.3 (23.28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>28 (43)</td>
<td>65.98 (18.25)</td>
<td>0.447 (63)</td>
<td>.66</td>
</tr>
<tr>
<td>Female</td>
<td>37 (57)</td>
<td>68.04 (18.50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wearables used</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xiaomi Mi Band</td>
<td>28 (43)</td>
<td>69.4 (19.30)</td>
<td>0.851 (63)</td>
<td>.40</td>
</tr>
<tr>
<td>Xiaomi Mi Band+Axivity AX3</td>
<td>37 (57)</td>
<td>65.5 (17.50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;70</td>
<td>23 (35)</td>
<td>71.3 (14.60)</td>
<td>0.411 (2)</td>
<td>.81</td>
</tr>
<tr>
<td>70-74</td>
<td>32 (49)</td>
<td>67.6 (19.30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;74</td>
<td>20 (31)</td>
<td>67.3 (23.30)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)SUS: System Usability Scale.

Analyzing the SUS Score by Cohort Region

SUS scores can be represented using either grades or acceptability ranges. Acceptability ranges use 3 categories: not acceptable (0≤SUS<50), marginal (50≤SUS<70), and acceptable (70≤SUS≤100) [30]. Analysis of SUS scores by region showed that Finland had both the largest (11/23, 48%) percentage in the marginal category and the lowest (2/23, 9%) percentage in the unacceptable category, making it the best-performing region given that scores in the acceptable category were similar across regions. Northern Ireland and Ireland performed equally well in both the marginal and acceptable categories, with 41% (9/22) of people. Sweden had the largest (9/20, 45%) percentage in the acceptable category, but conversely, scored the worst in the unacceptable category (6/20, 30%). Across all regions, a total of 43% (28/65) of people thought that the device had an acceptable SUS score of >70.

As shown in Figure 2, the distributions were not identical; therefore, a 1-way ANOVA was applied to compare the mean ranks. The results presented in Table 3 show that the differences between the mean ranks of the SUS scores for each region were not statistically significant.

The group means were compared using a 1-way ANOVA. A Levene test was performed, resulting in a P value of .85; therefore, the variances can be assumed to be homogeneous, and equal variances are assumed. Observing the normal quantile-quantile plots for each region in Figure 3, the quantiles mainly lie on or close to the red line, suggesting a normal distribution.

On the basis of the results in Table 3, the means of the SUS scores for each region were not statistically significant.

Figure 2. Histogram of System Usability Scale (SUS) categories from each region.
Analyzing the SUS Score by Sex, Number of Wearables Used, and Age

An independent-sample $t$ test was conducted to compare the SUS score between (1) the sexes and (2) the number of wearables used. The results suggest that there was no statistically significant difference in perceived system usability either given the participants’ sex ($P=.66$) or whether the participants wore 1 or both activity trackers ($P=.40$).

To analyze the SUS score by age, a Kruskal-Wallis $H$ test was conducted, allowing for a comparison between the 3 age categories. The Levene test $P$ value was <.001; therefore, the variances can be assumed to be not homogeneous. The results from the statistical test suggest that the means of the SUS scores for each age category were not statistically significant ($P=.81$).

Each of the SUS analyses showed that, regardless of comparing region, sex, wearables used, or age, there was no difference in perceived system usability.

Bespoke Usability Questionnaire

Overview

The final question in the bespoke usability questionnaire asked the participants if they intended to continue using the device after the trial had finished. In total, 65% (42/65) of the participants said that they would like to continue using the wearable device and phone app, whereas 35% (23/65) of the participants said that they would not like to continue using the device compared with participants who indicated that they would not continue using the device.

To evaluate whether there was a significant difference in SUS scores between participants who indicated that they would continue using the device and participants who indicated that they would not, an independent $t$ test was performed on the SUS questionnaire scores. The results are presented in Table 4. The participants who indicated that they would continue using the device averaged an SUS score of 71.8; thus, the “continue using” group on average considered the usability of the device to be within the “acceptable” category (range >70). In comparison, those who indicated that they would not be interested in continuing to use the device averaged an SUS score of 51.7 and, thus, the “not continue using” group on average ranked the usability of the device within the “marginally low acceptability” category (range >50 and <65). Results from an independent $t$ test showed that the SUS scores of the 2 “continued use” groups were statistically significant.

In addition to comparing usability with the intention to continue using the device, we evaluated what effect previous activity tracker experience (usability question 2) had on usability. In total, 20% (13/65) of the participants said that they had previously used a wrist-worn activity tracker, whereas 80% (52/65) of the participants said that they had never used a...
wrist-worn activity tracker before the trial. Statistical significance was evaluated for the SUS score of participants who had previous experience versus those who did not have previous experience. The results from an independent *t* test (Table 5) showed that there was no significant difference between a user’s SUS score and whether they had previous experience with a wrist-worn activity tracker (*P* = .28).

Further analysis was performed on the intention to continue using the device (question 21) to evaluate how continued use was linked to other human factor and usability elements. Therefore, correlations between question 21 and the other bespoke questions were analyzed. The description of the correlation values and associated rank are presented in Table 6, where the direction of the relationship is indicated by the sign of the coefficient. The results of the Kendall τb rank correlations are presented in Table 7. The results revealed 5 usability questions that had a strong correlation with the continued device use question. Questions 10 and 17 were the top-ranking features, each with a *P* value of .003, highlighting that both comfort at night and becoming more active are key early indicators of whether a user will continue using and wearing a device.

Further analysis was performed to evaluate the possible links between participants’ physical function and continued use in the future. Two 10-m walk test measurements and a sit-to-stand test (WT10M1, WT10M2, and STS5) were compared with continued device use using the Kendall rank correlation coefficient. On the basis of question 17 (Using the activity tracker helped me be more active) being highly correlated with continued device use, the aim was to assess whether physical function, measured before the study period, influenced continued device use. The results of this analysis are presented in Table 8. The results showed that none of the 3 physical function measures—WT10M1, WT10M2, and STS5—correlated with continued device use. This indicates that physical function before using the device is not likely to influence whether the participant will continue using the device in the future.

**Figure 4.** Histogram of the System Usability Scale (SUS) scores of the 2 different continued use groups.

**Table 4.** Summary statistics of the System Usability Scale scores for question 21 (N=65).

<table>
<thead>
<tr>
<th>Continue to use the wearable device?</th>
<th>Participants, n (%)</th>
<th>Values, mean (SD)</th>
<th><em>t</em> test (df)</th>
<th><em>P</em> value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, I would like to</td>
<td>42 (65)</td>
<td>71.8 (17.08)</td>
<td>−2.92 (63)</td>
<td>.005</td>
</tr>
<tr>
<td>No, I am not interested</td>
<td>23 (35)</td>
<td>58.7 (17.64)</td>
<td>−2.92 (63)</td>
<td>.005</td>
</tr>
</tbody>
</table>

**Table 5.** Summary statistics of the System Usability Scale scores for question 2 (N=65).

<table>
<thead>
<tr>
<th>Previously worn an activity tracker?</th>
<th>Participants, n (%)</th>
<th>Mean (SD)</th>
<th><em>t</em> test (df)</th>
<th><em>P</em> value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>13 (20)</td>
<td>72.12 (15.61)</td>
<td>−1.10 (63)</td>
<td>.28</td>
</tr>
<tr>
<td>No</td>
<td>52 (80)</td>
<td>65.91 (18.81)</td>
<td>−1.10 (63)</td>
<td>.28</td>
</tr>
</tbody>
</table>

**Table 6.** Kendall τb correlation ranks.

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>±0.10(^a)</td>
<td>Very weak</td>
</tr>
<tr>
<td>±0.10 to 0.19</td>
<td>Weak</td>
</tr>
<tr>
<td>±0.20 to 0.29</td>
<td>Moderate</td>
</tr>
<tr>
<td>±0.30</td>
<td>Strong</td>
</tr>
</tbody>
</table>

\(^a\)A positive sign indicates a positive relationship, and a negative sign indicates a negative relationship. A ± value means that the correlation value can either be positive or negative for each rank (eg, a 0.15 correlation would be weak, as would a −0.15 correlation).
Table 7. Continued device use Kendall $\tau_b$ correlation for each usability question.

<table>
<thead>
<tr>
<th>Question number</th>
<th>Question</th>
<th>Rank</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>The activity tracker was comfortable to wear at night.</td>
<td>0.348</td>
<td>.003</td>
</tr>
<tr>
<td>17</td>
<td>Using the activity tracker helped me be more active.</td>
<td>0.340</td>
<td>.003</td>
</tr>
<tr>
<td>15</td>
<td>The activity tracker accurately tracked my physical activity.</td>
<td>0.317</td>
<td>.005</td>
</tr>
<tr>
<td>6</td>
<td>I was able to wear the device easily without help from another person.</td>
<td>0.308</td>
<td>.009</td>
</tr>
<tr>
<td>9</td>
<td>The activity tracker was comfortable to wear during the day.</td>
<td>0.306</td>
<td>.01</td>
</tr>
<tr>
<td>4</td>
<td>I think that monitoring my health 24 hours a day, 7 days a week is a good thing.</td>
<td>0.264</td>
<td>.02</td>
</tr>
<tr>
<td>5</td>
<td>I am comfortable with my health data being stored on the internet.</td>
<td>0.264</td>
<td>.02</td>
</tr>
<tr>
<td>13</td>
<td>I had no concerns about my privacy while wearing the device.</td>
<td>0.253</td>
<td>.04</td>
</tr>
<tr>
<td>2</td>
<td>Have you previously used a wrist-worn activity tracker before the project?</td>
<td>0.209</td>
<td>.09</td>
</tr>
<tr>
<td>14</td>
<td>I was happy to wear the sensor in public.</td>
<td>0.206</td>
<td>.08</td>
</tr>
<tr>
<td>8</td>
<td>I was able to perform my daily tasks as usual while wearing the device.</td>
<td>0.202</td>
<td>.09</td>
</tr>
<tr>
<td>18</td>
<td>Over the last week, how many days did you wear the device?</td>
<td>0.187</td>
<td>.12</td>
</tr>
<tr>
<td>19</td>
<td>Did you wear it at nighttime?</td>
<td>0.169</td>
<td>.18</td>
</tr>
<tr>
<td>16</td>
<td>I was happy to wear the sensor around the house.</td>
<td>0.164</td>
<td>.18</td>
</tr>
<tr>
<td>12</td>
<td>I was able to put on the device in a reasonable amount of time.</td>
<td>0.119</td>
<td>.31</td>
</tr>
<tr>
<td>1</td>
<td>Have you heard of wearable smart devices before the project?</td>
<td>0.115</td>
<td>.36</td>
</tr>
<tr>
<td>7</td>
<td>I was able to remove the device easily without help from another person.</td>
<td>0.083</td>
<td>.50</td>
</tr>
<tr>
<td>20</td>
<td>Did you remove the device during the day for reasons other than getting the device wet?</td>
<td>−0.078</td>
<td>.53</td>
</tr>
<tr>
<td>3</td>
<td>Did you like the appearance of the wrist-worn activity tracker?</td>
<td>0.054</td>
<td>.66</td>
</tr>
<tr>
<td>11</td>
<td>I was concerned that the device was not securely attached to me.</td>
<td>−0.019</td>
<td>.87</td>
</tr>
</tbody>
</table>

Table 8. Continued device use (question 21) Kendall $\tau_b$ correlation for each walking activity feature.

<table>
<thead>
<tr>
<th>Question</th>
<th>Rank</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>WT10M1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>−0.194</td>
<td>.06</td>
</tr>
<tr>
<td>WT10M2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>−0.083</td>
<td>.42</td>
</tr>
<tr>
<td>STS5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.057</td>
<td>.58</td>
</tr>
</tbody>
</table>

<sup>a</sup>WT10M1: 10-m walk test time 1.
<sup>b</sup>WT10M2: 10-m walk test time 2.
<sup>c</sup>STS5: Five-Time Sit-to-Stand test.

Some qualitative data were also recorded using the bespoke usability questionnaire. Namely, participants were asked to provide any comments on the activity tracker that were not covered by the previous 21 questions. Some participants commented that the fastening buckle used by the Xiaomi Mi Band 3 was difficult to secure at times, which is likely to have affected scoring on questions related to comfort and donning and doffing (questions 6, 7, 9, 10, 11, and 12). In addition, some participants reported that they believed that the wearable sensor had to be fastened extremely tightly to obtain an accurate reading. This factor may have also influenced their comfort perception.

A Predictive Model for Continued Device Use

To train the predictive model, features were chosen from the results of the Kendall $\tau_b$ correlation from Table 7. A total of 3 feature subsets were chosen. The first subset was based on the 2 highest-correlated features (questions 10 and 17) such that the selected features had a $P$ value of ≤.005. A second subset was selected to include features with a $P$ value of ≤.01 (questions 6, 9, 10, 15, and 17). Finally, a third subset was selected to include features with a $P$ value of ≤.10 (questions 4, 5, 6, 9, 10, 13, 15, and 17). For the remainder of the paper, the models developed using each of the 3 feature subsets will be known as the 2-feature model, 5-feature model, and 8-feature model.

Initial experimentation was performed using multiple classifiers to obtain a performance baseline. This preliminary experimentation tested the following classifiers: decision tree, support vector machine, random forest, and k-nearest neighbor. From this experimentation, we found that random forest provided the highest predictive performance in classifying whether users would have an intention to continue using the device after the trial ended. For comparison with the random
forest models, regression multinomial models were also performed. These multinomial models are helpful for the simplicity and interpretability of the predictive model.

For the multinomial models, all data were included to observe and assess the statistical or discrimination power of the model at once. For the random forest models, validation of the final classification was achieved using a train-test split validation of 70 to 30 to check model accuracy.

The results from each of the 2-, 5-, and 8-feature models for both the multinomial and random forest models are shown in Table 9.

<table>
<thead>
<tr>
<th>Number of features and class type</th>
<th>Multinomial model—predicted class</th>
<th>Random forest model—predicted class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>2 features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual class</td>
<td>No</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>5</td>
</tr>
<tr>
<td>5 features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual class</td>
<td>No</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>4</td>
</tr>
<tr>
<td>8 features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Actual class</td>
<td>No</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>4</td>
</tr>
</tbody>
</table>

The findings from the multinomial 2-feature model display an overall accuracy of 80%, and the findings from the random forest 2-feature model correlate with an average accuracy of 80%, an average precision of 0.80, and an average recall value of 0.80. Both sets of results show that a reasonably accurate prediction can be made for usability question 21.

After increasing the model’s features to 5, the multinomial model displays an overall percentage of 83.1%, and the random forest model correlates with an average accuracy of 80%, an average precision of 0.80, and an average recall value of 0.80. The multinomial results improved slightly compared with the findings from the 2-feature model, whereas the random forest results remained the same.

The final model used 8 parameters. The findings from this multinomial model displayed an overall percentage of 84.6%, whereas the random forest model’s average accuracy increased to 85%, displaying an average precision of 0.88 and an average recall value of 0.85. Both sets of results improved from the 2-feature and 5-feature model findings. Nonetheless, the improvement from the 2-feature model to the 8-feature model was 5%.

**Discussion**

**Principal Findings**

Analysis of the usability of the wearable system by older adults indicated a significant correlation between usability and intention to continue using the system. Comparing SUS scores of participants who intended to continue using the device with SUS scores of those who did not resulted in a statistically significant difference ($P=.005$). On average, users who indicated that they would continue using the wearable device also indicated that the device had good usability, whereas users who indicated that they would not continue using the wearable device indicated that the device had poor usability. Therefore, participants who found the system easier to use were also more likely to want to continue using it. These results are in line with previous research findings that suggest that ease of use and device usability are important measures for technology acceptance yet are often overlooked in favor of device accuracy [7].

Additional evaluations conducted using the standardized SUS scores showed that neither sex, age, geographical location, previous experience, nor the number of wearable devices used influenced the results of system usability. Although a subset of participants wore 2 activity trackers, the results showed no statistical difference in SUS score depending on whether the participant was asked to use 1 or 2 wearables. This is likely because 2 wrist-worn sensors are still deemed unobtrusive in everyday life. Further research is required to observe whether these results can be scaled based on anatomical location or additional wearable sensors.

Furthermore, there was no statistically significant difference in the usability scores for a wearable sensor system regardless of whether the participant had previous experience using a wearable device. This finding implies that technology literacy is not necessarily an influencing factor when it comes to the perceived usability of a wearable device. A possible explanation for this finding is that each participant in the study received a standardized training session lasting 10 to 15 minutes at the...
beginning of the trial and a user manual for reference. These results indicate that a lack of experience using wearable devices does not need to be a barrier to adoption if appropriate training can be provided.

Usability is clearly an influencing factor for continued device use. However, there are other human factors that could influence continued use. A 21-question bespoke questionnaire was used to further evaluate these human factors. The results showed that the human factors that had the strongest correlations with continued device use were (1) device comfort at night and (2) perception that the device helped increase activity. Inspecting the 5 questions that correlated the most with continued device use, 3 of the questions related to human factors, whereas 2 related to perceived accuracy.

On the basis of feature subsets from 8 questions that correlated the most with continued device use, machine learning models were implemented to predict whether a participant would indicate that they would continue using a wearable device. These 8 questions related to opinions on comfort, data privacy concerns, and the participants’ perception (beliefs or attitudes) of device accuracy or monitoring their health. These models have the potential to act as an early indicator of participants not continuing to use the device. Factors such as discomfort at night can be identified early before users decide to stop using it. This may allow for interventions to be made to address user concerns early in research studies, for example. As an additional benefit, the accuracy of these models provides insights into what design features are important to encourage wearable technology uptake in older adult populations.

The results indicated that the models could predict the likelihood of a participant having an intention to continue using the device with 80%–85% accuracy. Interestingly, the accuracy of the model only dropped by 5%–80% when we greatly simplified the questionnaire and only selected the top 2 correlated questions for prediction. As mentioned, these questions were related to evening comfort and whether the device helped increase activity levels. These results indicate that, by using a simple 2-question survey approach, it is possible to make accurate predictions about the likelihood of an older adult wanting to continue using a wearable device. This is useful as focus groups could leverage these questions to gain meaningful insights into their product development, or these questions could be included in a mobile app or web-based application to frequently report the usability of wearable products to ensure client satisfaction and better standards of quality assurance.

Future design of devices should keep in mind that wearable sensors are likely to be used by older adult patients with health complaints who often have reduced fine motor skills [31]. Therefore, to ensure maximum customer buy-in, manufacturers need to ensure that such devices are easy to don and doff.

Comparison With Previous Work

Most research on wearable sensor technologies currently places accuracy at the center of the design. This often comes at the expense of usability, which can ultimately have negative effects on continued device use [6]. Previous research suggests that, to achieve successful adoption of remote rehabilitation technologies, the solution must be both practical and usable [8]. This is particularly relevant when considering wearable sensor systems.

Previous research has been conducted on usability evaluations by older adults using activity trackers [32]. This study asked 20 older adults to evaluate 5 different activity trackers over a 2-hour period. On average, the trackers tested in that study had an SUS of 56.38 (SD 11.86). Although a different cohort, review time, and number of devices were used, it is interesting to note that the Xiaomi Mi Band 3 used in our study, evaluated across 4 independent locations, obtained a similar average SUS score of 67.15 (SD 18.27) compared with the top-performing trackers in the previous study: the Fitbit Flex (SUS=66.25) and Nike FuelBand (SUS=65). SUS scores for the Xiaomi Mi Band 3 in this study were significantly higher than those of the other 3 sensors assessed by Steinert et al [30]. There is some evidence collected using postinterviews with some participants suggesting that the high score obtained by the Xiaomi Mi Band 3 may be related to a specific element of comfort. Participants indicated that the rubber material of the activity tracker made the device very comfortable to wear.

To achieve the potential health benefits presented by wearable sensors and remote digital health technologies for older adult populations, it is vital that users continue to use the wearable sensors over long periods. However, there is limited work in the literature exploring the factors that influence long-term wearable device use among older adults.

Strengths and Limitations

One of the key strengths of this study is that it assessed a broad spectrum of factors that could potentially influence continued device use among a diverse set of participants. This study provides clear evidence that usability, comfort, and motivation are key elements that must be considered for any wearable sensor-based application requiring long-term use.

There are some limitations to this study that could be addressed in future research. First, the sample size was limited to 65 participants, and as such, may not be large enough to provide accurate insights into the behaviors of older adults. This limitation was imposed as data collection had to cease at the onset of the COVID-19 pandemic. Second, there may be bias in the results owing to the ethics approval granted for the study. Given that participants were to have no underlying health conditions other than frailty, the vast majority of the volunteers were considered healthy, reflected by the mean score of 72.54 achieved for general health in our cohort, calculated using the SF-36 questionnaire. To contextualize this, in a normative study on older adults (N=8117; aged ≥65 years) where no screening was imposed, the mean general health score was 53.06 [33]. The factors that influence continued device use may be different for older adults considered unhealthy. To verify this, further research with a larger cohort of both healthy and unhealthy participants would be required. Third, although the findings of this study are based on the Xiaomi Mi Band 3, it is unknown whether they would be transferable to other devices. Therefore, further research would be required administering the same bespoke usability questionnaire to older adults testing a range of wearable sensor devices.
Conclusions
This study used a combination of validated questionnaires to gather 65 participants’ opinions on the usability of an off-the-shelf wearable sensor system, the Xiaomi Mi Band 3. To gain further insights into the factors that may influence an older adult intending to continue using a wearable device, we also designed a bespoke usability questionnaire for this study. Various analyses were performed examining the statistics from the pretrial questionnaires; summary statistics of the SUS score with respect to region, sex, wearables used, and age; and findings that focused specifically on the final question from the bespoke usability questionnaire to determine what factors influence continued device use.

The results from the SUS show that there was no notable difference in perceived system usability depending on region, sex, age, or previous experience, eliminating the notion that usability perception differs based on geographical location, sex, or deviation in participant age. Previous studies have suggested that usability and ease of use are as important as device accuracy when it comes to technology acceptance and device uptake. One of the main lessons learned from the results of this study was that the most important factor that influenced continued device use in an older adult cohort was device comfort. Feeling that the device was fit for purpose (ie, it helped them achieve the task it claimed it would) was the second most important factor. In addition, it was observed that comfort matters the most when a wearable device is used while sleeping. These lessons could better inform the design of future wearable sensor systems for applications specifically targeting older adults.

We presented a random forest model with 80% accuracy using these 2 features, which could be used as an early identifier of continued device use—for example, if the user is asked these 2 questions after the first day of the study, their response would be a clear sign of whether they are interested in using a wearable sensor system long-term. After including the top 8 ranked questions from the bespoke questionnaire as features of our model, the accuracy increased to 88%.

Acknowledgments
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Data Availability
The data sets generated and analyzed in this study are not publicly available as the data contain information that could compromise the privacy of the research participants. The data are available from the corresponding author upon reasonable request.

Authors’ Contributions
KME, JG, DK, and ST contributed to conceptualization. KME, JG, DK, and ST contributed to methodology. KME, JG, DK, WD, and CM contributed to analysis. KME, JG, DK, WD, and CM contributed to writing (original draft preparation). KME, JG, DK, JC, RD, WD, CM, EN, AA, JJ, ST, and JB contributed to writing (review and editing). JC contributed to funding acquisition. All authors read and agreed to the published version of the manuscript.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Accuracy, feasibility and acceptability of wireless monitoring in older people: posttrial usability questionnaire.
[DOCX File, 27 KB - aging_v6i1e36807_appl1.docx ]

References


Abbreviations

GDS: Geriatric Depression Scale
MDPQ: Mobile Device Proficiency Questionnaire
MMSE: Mini-Mental State Examination
SF-36: 36-item Short Form Health Survey
STSS: Five-Time Sit-to-Stand test
SUS: System Usability Scale

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Development of a Smart Home Interface With Older Adults: Multi-Method Co-Design Study

Abir Ghorayeb¹, BSc, MSc, PhD; Rob Comber², DPhil; Rachael Gooberman-Hill¹, MA, DPhil

¹Faculty of Health Sciences, Bristol Medical School, Bristol, United Kingdom
²Department of Media Technology & Interaction Design, KTH Royal Institute of Technology, Stockholm, Sweden

Corresponding Author:
Abir Ghorayeb, BSc, MSc, PhD
Faculty of Health Sciences
Bristol Medical School
Musculoskeletal Research Unit
Bristol, BS105NB
United Kingdom
Phone: 44 7786268261
Email: abir.ghorayeb@bristol.ac.uk

Abstract

Background: Smart home technologies have the potential to support aging in place; however, older people’s perceptions of the value of smart homes may be influenced by their access to the information gathered by the technology. This information is needed to support their informed decision-making. Limited research has been conducted on how best to design visualizations of smart home data in keeping with the needs and wishes of older people.

Objective: We aimed to investigate the design options that impact the usefulness of smart home systems, older people’s information needs, their perceptions of data visualization, and the ways they would like information displayed to them.

Methods: We used a qualitative approach to empower the participants as co-designers. Data collection comprised a sequence of methods such as interviews, observation, focus groups, scenario design, probes, and design workshops. Each phase informed the next. Overall, 13 older adults (n=8, 62% female and n=5, 38% male; aged 65-89 years) consented to participate. A thematic approach was used to analyze the data set, and participants were actively involved in designing the in-home interface, which enabled them to better conceptualize their needs.

Results: The information collected was clustered into 5 themes: enabling home, health, and self-monitoring; enabling opportunities for social inclusion and engagement; enhancing cognitive abilities; customizability of the display; and promoting inclusion in recreation and leisure activities. These themes informed 5 design sessions in which participants co-designed visual metaphors for the themes based on their own experiences in an age-inclusive manner. Together, the participants produced a user-friendly prototype, which they chose to call My Buddy. They found it useful to receive social and cognitive triggers, as well as recommendations for special diets or activities based on their mood, health, and social status.

Conclusions: Smart home data visualization is much more than a nice-to-have option. Visualization is a must-have feature because it deepens the understanding of the information collected and means that technology provides information of value and relevance to older people. This may improve the acceptability and perceived utility of in-home technology. By understanding what older people want to know from smart home technology and considering how to visualize data in ways that work for them, we can provide an appropriate in-home interface. Such an interface would suggest ways or opportunities to connect and socialize; stimulate contact with close friends or family members; maintain awareness of health and well-being; provide support in decision-making, cognitive tasks, and daily life activities; and monitor health status. Older adults are the best co-designers for the development of visual metaphors that resonate with their own experiences. Our findings promote the development of technologies that foreground and reflect the information needs of older people and engage them as designers of the display.

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KEYWORDS

data visualization; digital health; smart homes; older people; technology acceptance; qualitative research; mobile phone

https://aging.jmir.org/2023/1/e44439
**Introduction**

**Background**

Smart home technologies for older adults are becoming increasingly popular. This growth is complemented by interest in older people’s information needs as well as those of professional and family caregivers and other stakeholders. Although research into information needs often includes stakeholders, few studies have involved older people in the design process to visualize sensor data [1-6]. By working with older people to identify the information that they need and how best to view, access, and share this information, research can address the possible barriers to the adoption of smart home technology [7-9]. Appropriately designed data visualizations can help older people make the best use of smart home technologies and promote their engagement in health care and social activities [7,10].

Most studies related to data visualization from monitoring technologies have only included researchers or clinicians [2,11-15]. Many older people recognize the value of data visualizations for personal use to track changes in health and wellness and to support their decision-making and cognition [7,16-18]. However, many older people do not have a priori knowledge of the types of data collected or what it might mean for their health and well-being [18].

Table 1 presents a selection of studies that address data visualization for older people as primary users. Most studies include visualizations that were designed by researchers or technical staff and were then evaluated to determine the usability and usefulness of the interface [19], sometimes based on findings from interviews or focus groups [1,3,18]. Data visualizations have been assessed through questionnaires [19], interviews [2,3,18-21], and focus groups [14,21,22] with older people. Although visualizations have shown potential to support older people in their daily activities, the usability of the display has been questioned. Concerns about usability relate to the ease of use and effectiveness of the interface in terms of the provision of information to users and facilitation of user interaction with the system. This suggests that such interfaces may have been challenging to use or failed to meet user requirements.

<table>
<thead>
<tr>
<th>Study author, year</th>
<th>Designed by researchers</th>
<th>Evaluated by older people</th>
<th>Information presented to older people</th>
<th>Participants</th>
<th>Evaluation methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Le et al [2], 2018</td>
<td>2 visualizations</td>
<td>Limited understanding of data</td>
<td>Health visualization</td>
<td>21 older people</td>
<td>Semistructured interviews</td>
</tr>
<tr>
<td>Reeder et al [3], 2014</td>
<td>3 visual displays</td>
<td>Useful for caregivers, no information about how data are useful for older people</td>
<td>Activity level, fall scenarios</td>
<td>7 older people</td>
<td>Semistructured interviews</td>
</tr>
<tr>
<td>Ayoade et al [23], 2013</td>
<td>2 visualization tools</td>
<td>N/A*</td>
<td>Home rehabilitations</td>
<td>5 people who have fallen and 6 patients with knee replacements</td>
<td>2 user studies: falls prevention and knee replacement rehabilitation</td>
</tr>
<tr>
<td>Mynatt et al [24], 2001</td>
<td>In-home interface</td>
<td>Complex design</td>
<td>Communication</td>
<td>1 grandmother and 2 grandchildren</td>
<td>Field trial</td>
</tr>
<tr>
<td>Doyle et al [20], 2015</td>
<td>Visualizations informed by interviews</td>
<td>Complex design, need for more information</td>
<td>Sleep activity, heart rate, weight, blood pressure, and activity level</td>
<td>7 older people</td>
<td>Semistructured interviews, focus groups</td>
</tr>
<tr>
<td>Le et al [1], 2014</td>
<td>1 sensor visualization, informed by interviews</td>
<td>Very difficult to understand</td>
<td>Activity data</td>
<td>8 older people</td>
<td>Semistructured interviews</td>
</tr>
<tr>
<td>Castelli et al [25], 2017</td>
<td>2 visualizations and 1 visualization creation tool</td>
<td>First version: hard to understand and complex design</td>
<td>Energy, temperature, security, diaries, and weather forecast</td>
<td>12 households (29 inhabitants, various ages)</td>
<td>3 interview studies, a design workshop, and system log data</td>
</tr>
<tr>
<td>Jo et al [10], 2021</td>
<td>Sensors available in the market</td>
<td>Complicated to understand and hard to read</td>
<td>Smart band and indoor air quality sensor’s display</td>
<td>9 older people</td>
<td>Focus groups</td>
</tr>
<tr>
<td>Caldeira et al [18], 2021</td>
<td>Informed by interviews</td>
<td>N/A</td>
<td>Activity status and heart rate Records</td>
<td>9 older people</td>
<td>Final product not evaluated</td>
</tr>
</tbody>
</table>

N/A: not applicable.

Nonetheless, older adults find value in data visualization through self-tracking [2,3]. In a 6-month pilot study, Reeder et al [3] found that visualizations of sensor data were useful for older people with cognitive impairment and their caregivers. This resonates with findings from a study by Le et al [2], in which they investigated the utility of health visualizations and potential barriers by introducing 2 visualizations to 21 older adults, followed by a semistructured interview. Similar studies developed visualizations to engage older people in home exercises [23] and showed that visualizations improved the ability and confidence of the participants compared with a booklet. Other studies have used graphs and icons to support older people’s understanding of blood pressure measurements [13]. As part of a pilot study to evaluate the feasibility of using
smart home devices to support aging in place, Choi et al [26] reported that participants were interested in accessing their activity level and environmental data to help them monitor and manage their health status. Visualization can also facilitate communication between older people, caregivers, and relatives [1,3,21,24] and offer a better understanding of health status [5].

Older people often face challenges in accessing and interpreting information, including data visualization. They may experience physical and cognitive changes that impact their information needs and ability to access such information. For instance, aging may be associated with changes in eyesight, cognition, and physical abilities, all of which should be considered in future visualization design [27,28]. In addition, in light of changes related to aging, some studies indicate that older people might find it difficult to locate specific information in complex interfaces, understand infographics, and control moving components [3,28,29]. Several studies have investigated the features of interfaces that can affect older people’s interactions with smart home technologies, such as the sliding method [30], bar graph [1], numerical representations, and button size [31,32]. Participants in such studies also expressed concerns about data visualization formats that have limited utility and can lead to data misinterpretation, and it is better to produce data visualizations that match older people’s own lives [32]. For instance, Mynatt et al [24] developed a digital portrait that comprised a visualization of the data collected from a motion sensor in a smart home with “butterfly” icons bordering the digital picture frame representing activity level of the participant. Mynatt et al [24] found that the design of the interface was too complex, as it conveyed 10 levels of information; however, the design did change activity levels of older people and triggered communication between them and their family members. Le et al [2] noticed that participants expressed interest in using visualizations as an intervention tool. In another study, Reeder et al [3] developed 3 interactive interfaces based on participants’ views of smart home technologies, and the evaluation phase revealed the need to reduce complexity and facilitate ease of use. Users found the bar charts difficult to understand, and the use of color created visual confusion for some. These findings were similar to those reported by Jo et al [10], who studied the usability of an indoor air quality sensor display, and by Castelli et al [25], who studied the usability of a set of sensor display by 29 participants.

A better understanding of older people and their home living environments is crucial to design appropriate technology for them [4]. Although certain studies concern data abstraction, to the best of our knowledge, there are no published studies focusing on the information needs of older people, such as how they would like to access the information and how to display it [4,5,18,33]. As Table 1 illustrates, when older people evaluate data interfaces, the data are often not presented in a way that is meaningful or appropriate for them. A substantial challenge in identifying and presenting these data lies in establishing tangible insights gathered from the real-life experiences of older people. For instance, older people are not usually familiar with the collected data sets that may require technical knowledge to understand. Furthermore, similar to people of any age, they might not be interested in all the information collected and need to select or customize what they want to visualize and access. Engaging older people as co-designers for creating visual metaphors derived from their culture or experience helps avoid ageism, with older adults having the option to select and customize the data to visualize, and helps to make the display appropriate to older people rather than creating a “big brother” style of approach [7]. Our research, which involved older people as co-researchers, highlights key points for consideration when designing visualizations for older people.

**Objectives**

Our aim was to identify and describe information that older people think is essential for supporting them in decision-making, daily life activities, and cognitive tasks. We aimed to identify the types of data that older people want to access so that together we could design an interface to visually represent such data and thereby enhance the usability and utility of smart home technology.

**Methods**

**Overview**

We followed a qualitative approach in this study. We used different methods to empower the participants as co-designers and partners, as shown in Figure 1. “Co-design is meaningful end-user engagement in research design and includes instances of engagement that occur across all stages of the research process and range in intensity from relatively passive to highly active and involved” [34]. The ethics of co-design derive from an approach to community engagement that aims to go beyond passive consultation with stakeholders so that communities or groups are actively engaged. This acknowledges the importance of real-world experience in the design process. It also recognizes that as stakeholders, communities will ultimately be the most affected by design outcomes and should therefore have great influence.

We used and customized a combination of well-known participatory co-design methods to achieve our objectives. The methods comprised interviews, observation, focus groups, scenario design [35], and probes [36] (Figure 1).
**Participant Recruitment**

Older people familiar with the SPHERE (sensor platform for healthcare in a residential environment) smart home technology [37] were identified and invited to participate in the study. In partnership with a local community engagement center, participants with no background in smart home technology were invited to participate. Through this partnership, we attended gatherings for older people, including an older people’s forum and dancing, knitting, and film clubs. We also placed participant information booklets in 2 public libraries, and we reached out to local organizations that support older people for assistance with the recruitment processes.

We contacted everyone who might be interested by sending out recruitment packs (invitation letters, participant information booklets, reply slips, and freepost envelopes). The aim was to include older people with a wide range of ages, education levels, health, and interests.

**Ethics Approval and Informed Consent**

The study was approved by the University of Bristol Faculty of Health Sciences Research Ethics Committee (approval 57781) on November 21, 2017.

All participants provided written informed consent to participate in the study, to be audio recorded, and to have anonymous quotations and photos to be published. The participants were given the opportunity to ask and clarify any concerns before signing the consent form. A copy of the signed consent form was provided to each participant, and a second copy was kept with the researcher and held securely in university premises. Participants were made aware that they could withdraw from the study at any time without explanation or repercussions. Participants in the focus groups and workshops were provided with refreshments, and travel expenses were reimbursed. Transcripts and notes were anonymized by removing details that could lead to participant identification. The names of the participants used in this study are pseudonyms.

**Preliminary Work: Focus Groups**

This work was informed by earlier findings cited in our previous work [7], in which 4 focus group sessions were conducted to investigate older people’s views and expectations of smart home technology. All participants had a positive view of smart home technology, although most participants did not recognize that they needed the technology at this point in their lives. However, the participants said that they would be willing to use such technology as they grew older or frail. In addition, participants said that they would be more receptive to the use of smart home technology if it provided access to their own health data or made it easier to participate in social events. They also wanted technology to offer new ways to have fun, shop, play web-based games, enroll in educational courses, communicate securely with others, assist family members, and fulfill other social roles. The findings of the focus groups informed our home visits and interviews.

**Home Visits and Interviews**

In total, 2 home visits were made to each participant to learn about their behaviors and attitudes toward the existing technology. The first visit comprised a semistructured interview. Discussions and observations were kept informal to reassure participants. Handwritten notes were taken, and the interviews were audio recorded. During this visit, participants were observed in their proper environment while they pointed out any item they considered particularly “smart” [38] (Figure 2). They discussed their technology use and attitudes in the context of their homes. This discussion was guided by the same topic areas. Explored topics included the use of everyday communications, privacy issues, and the identification of information needs. The first section included information about the person such as occupation, age, sex, activities, leisure, family status, the number of children and close friends, and technology use. We also attempted to learn more about the participants’ state of health, physical abilities, and particular incidents (eg, falls). In the second section, participants were asked their opinions about aging at home, smart home technology, and the reasons why older people move home. Finally, we discussed any concerns or worries that smart home technology raised and their attitudes toward being monitored and communicating remotely. The participants described activities they could no longer perform but which technology made possible and the communication issues they encountered. During the visits, the activities were flexible, depending on each participant’s abilities, interests, and capabilities.
Probes

Cultural probe techniques [35] were used to empower the participants to share their preferences and knowledge. Cultural probes allow participants to report information about themselves and their values, thoughts, and activities. Information gathered during the first visit informed the design of our cultural probe kit, which included a camera, a diary, and questionnaires given to participants to record specific events. We began by sketching the layout of the probe on paper, ordering the questions, and leaving space for responses. Subsequently, we created and tested a prototype within the team. Our goal was to optimize the design for accessibility, attractiveness, and ease of use to ensure better results. We then conducted a trial period of 3 days with 3 participants, collecting their feedback and integrating it into the probe’s design. This included making a few questions clearer, avoiding repetition, and incorporating a scale to reflect the participants’ daily moods. After incorporating the initial feedback received, the final design revisions were made. We gathered insights into participants’ environments that helped to identify specific issues, uncover new opportunities, and inspire the development of new design concepts. Kits were delivered to the participants in person so that each item and the overall purpose of the research could be explained. These activities were entirely voluntary, and of the 13 participants, 9 (69%) participants agreed to complete the probe kit process. They had 1 month to complete and return the documents after completing as much as they desired. Of the 9 participants, 6 (67%) completed all the elements of the probe kits.

Design Workshops (My Buddy)

The focus group, home visits, interviews, and probe findings informed the design phase, in which we used iterative group design sessions. Of the 13 participants, 5 (38%) participants agreed to participate in the design activities. In the first session, we presented and discussed the findings of the previous phases together on a whiteboard (Figure 3) and asked the participants to identify the functionalities they would like to include in the visualization of the “in-home interface.” They were asked to write down each functionality using their own words on sticky notes (Figure 4).

In the second session, we presented all the sticky notes on a wall and took pictures of the participants organizing and discussing the different information, as pictures were the best way to capture the details. Participants were asked to group these items by topic and to give each topic an appropriate title.
The sticky note for the title differed in color and shape (Figure 5).

In the third session, we divided the participants into 2 groups and asked them to draw the main interface, resulting in 2 different prototypes by the end of the session. After a thorough discussion between the 2 groups, they selected 1 interface for development. The participants called this My Buddy (Figure 6).

In the last session, the participants evaluated the interface built using the Adobe XD software (Adobe Inc). We presented early prototypes to older people through focus groups. On the basis of these findings, we refined the interactive interface design. They suggested some improvements and proposed adding more features such as bus timetables and levels of pollen. We then developed the final version of My Buddy (Figure 7).

Figure 3. Summary of findings.

Figure 4. Participants using their own words to describe each functionality they wanted.
Figure 5. Participants organizing data.

Figure 6. Participants drawing the main interface.
Results

Participants

In total, 13 older adults, aged between 65 and 89 years, with varying levels of education, health, and interests, were recruited through various channels. Of the 13 participants, 7 (54%) had prior experience using smart home technology in their homes for 8 to 12 months as part of the SPHERE project [6]. The remaining 6 (46%) of the 13 participants were members of the public who had never used smart home technology.

Table 2 summarizes the participant characteristics. Of the 13 participants, 2 (15%) participants self-identified as belonging to a minority ethnic group, and 5 (38%) participants were male. Of the 13 participants, 8 (62%) participants lived alone in their homes or apartments, whereas the rest (n=5, 38%) lived with their partners. Of the 13 participants, regarding educational background, 3 (23%) participants held school qualifications, 3
(23%) participants completed university degrees, and 7 (54%) participants had postgraduate degrees. Of the 13 participants, 2 (15%) participants had never worked before, and 1 (8%) participant was employed part time as a researcher. Most of the participants were retired but remained active and volunteered at various locations.

### Table 2. Participant characteristics.

<table>
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<th>Participants’ pseudonym</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Qualification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>Male</td>
<td>73</td>
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</tr>
<tr>
<td>Alice</td>
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<tr>
<td>Bethan</td>
<td>Female</td>
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<tr>
<td>Christine</td>
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<tr>
<td>Daniel</td>
<td>Male</td>
<td>81</td>
<td>Degree qualification</td>
</tr>
<tr>
<td>George</td>
<td>Male</td>
<td>81</td>
<td>Postgraduate qualification</td>
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<tr>
<td>Florence</td>
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<td>Molly</td>
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<td>Izzy</td>
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<tr>
<td>Jemma</td>
<td>Female</td>
<td>74</td>
<td>School qualification</td>
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### Interviews and Probes Analysis

**Data Analysis**

The probe kits produced diverse results, as illustrated in Figure 8. Initially, we read through and cleaned the probe documents and notes to remove unrelated data. Some participants provided detailed accounts of their daily routines, including their trips to stores, items they purchased, and people they met. These activities helped us gain valuable insights into their daily lives and inspired the design ideas that we explored with the participants. We then conducted an inductive thematic analysis of the interviews, probe documents, and notes, with the first and last authors collaborating on the coding and theme development. Regular data meetings were held to discuss and modify the content and analysis, including the coding and thematic development. We read and reread the transcripts, assigned codes to the data, and classified them into themes and categories [39]. As the interview feedback informed the probe questions and activities, the data analysis of one supplemented the study of the other with a number of overlapping themes.

As a result of the previous phase, most participants requested more functionalities and information from the smart home systems [7]. On the basis of the codes, we grouped the data and themes into different categories linked to enabling home and health monitoring and self-monitoring; enhancing opportunities for social inclusion and engagement; enhancing cognitive abilities; customizing the display; and promoting inclusion in recreation and leisure activities.
Enable Home, Health, and Self-monitoring

Participants were eager to track their health, behavior, and homes. They looked for particular details.

Health Parameters, Diet, and Auto-order Medication

The participants were keen to understand and manage their blood pressure, cholesterol and blood sugar levels, pulse, and activity levels. They requested results over time to help them track any changes and better manage their lifestyles. We noticed that each participant suggested what they thought was better for their health status. Some participants used the health portal to order their prescriptions:

...blood, cholesterol level and blood sugar level,...I could actually read about results for things and work out what a good blood sugar level is or not and I can perhaps do something about my lifestyle...the results of my pulse's activity through the course of a day or through the course of a week or through the course...
of a month and I think for something to be perhaps meaningful, it needs to be seen in the context of time...
[Henry]

...[She uses the health portal] To order my prescriptions... [Kelly]

...When I run out of the drugs I’m using the health portal, that goes straight to the surgery. [Daniel]

Participants believed that a smart home could help them by providing a diet plan tailored to their specific health concerns. The new interface would offer an easy-to-follow recipe considering the health conditions of each person:

I’m sure there would be things around cooking. [Bethan]

If I can do something about having a healthy lifestyle or improving my health, then, if it’s about diet, if it’s about exercise, it’s about things, that I guess that might improve my health or longevity or chances of remaining healthy, then I’m interested. [George]

Enable Remote and Self-monitoring

Participants explained that they used to do some activities that they could not do anymore, such as running for the bus or going to the gym. Most participants were affected by age-related diseases and cognitive impairment. Smart home data might be used to drive behavior change, as participants wanted the system to recommend a walk, TV program, or other activities that the system indicated that they would enjoy or find helpful:

...like tell me how much I’ve moved all day and like how far I’ve walked or something...It is like if something had come on the telly every day and said, “Now Bethan, we’re going to do our exercises. Sit in the chair,” and I would have felt like I’d seen somebody and talked to somebody...You don’t think you’ve slept very much. Actually, it would be quite good to know, you’ve got five hours sleep or six hours sleep a day...I think things like that [monitoring steps around the home] so that you could think, “Oh, I must up it a bit,” or “Oh gosh! I’ve done well,” Could get some feedback for myself. [Bethan]

Because I think from the data you could monitor your life because you don’t monitor yourself, right, and I could be sitting here watching TV for about four hours and then if you keep on looking at the data, this is what you are doing every day, you will think my God is this what I’m doing, maybe I should do something different, I should go out for a walk or something, so it’s quite important. [Molly]

I would expect it to monitor my behaviour and my presence in the house or the environment...if it could choose a TV programme that it knows that I like or a radio programme which I really enjoy. So I could use something which would select things and draw my attention to them so that I could not miss a good radio programme on a Thursday morning, for instance... [Edward]

If an emergency arose, all participants said that they would agree to share their data with trusted people only:

I mean if I was lying on the floor, and I hadn’t got my mobile phone or the landline nearby, I would want to be able to shout and know that some speaker is going to pick it up. And if there was something that you could trigger off an alarm response, then I think that would be a very good idea. I wouldn’t want to be found a week later. [Kelly]

If I was being monitored for certain things by a healthcare professional of some kind, I wouldn’t necessarily want to be engaged with that. I would be happy to, abdicate responsibility and allow that information to be used on the understanding that it was for my benefit in the end anyway. [Edward]

...I suppose things like Google and Alexa that would be helpful because, you might fall but you can’t move, so you could say, Alexa get help and that should be helpful. I think I would want it as part of a care package. [Izzy]

Most participants wanted to keep control of the system in all cases as described in the study by Ghorayeb et al [7].

Enable Home Monitoring

Participants required home monitoring, as they believed that smart home technologies should accommodate common aging frailties such as lower vision, decreased mobility, increased risk of falls, and cognitive decline. They wanted to feel safer and have assistance with their daily duties. They required smart lights for dark passageways, smart plugs, and the ability to monitor who is at the entrance. They wanted the technology-enabled reminders to close an open tap or switch off the oven when necessary. They wanted to control the room temperature, air quality, and electricity consumption:

Monitor the environment itself maybe, temperature, er, yeah high temperature or low temperatures, Maybe monitor some of the appliances to see whether they were on too long or something like that...I could see whether, got a leaking tap for instance, whether someone’s left the tap on... [Edward]

I think that it would be very useful if you could look at that information and say “I’m leaving too many lights on, I’m using too much electricity”... [Jemma]

...The front door opening and closing is one of things that they would monitor as well as say the kettle and say the microwave or perhaps a toilet or... [Christine]

I think I would expect a smart home to monitor air conditioning and turn on filters if it thought it was necessary. I would expect it if a room is not occupied and the sun is shining brightly through it and it’s in the middle of summer, I would expect it to close blinds so that the room would not get unnecessarily hot...monitor air quality and levels of background noise...air quality. [Daniel]

(77%) of the 13 participants agreed to share their data with trusted people only:
**Enhancing Opportunities for Social Inclusion and Engagement**

**Overview**

Although social engagement has always been associated with better health and quality of life [40], it is still a real concern for older people because of the life-changing events that can be associated with aging. Although all the participants considered in-person visits as the best means of communication and interaction, they highlighted the importance of the new interface being able to suggest new ways or opportunities to connect and socialize and stimulate contact with close friends or family members. Through the probe activities, we identified the social networks of the participants, that is, the number of contacts with relatives and friends, memberships in charitable or social groups or organizations (church services), and so forth (Figure 8).

**Communication Opportunities and Social Activities Engagement**

The way that older people socialize and interact is changing, especially given their increasing use of communication technology and the role this can play in supporting social engagement. Most of the participants had already used social engagement technologies such as email, Facebook, and WhatsApp (few participants used Twitter):

I spend a bit of time doing emails and business and friends emails. [Liam]

We have a little family WhatsApp. So we do often share something that will come up or they’ll send a picture... [Alicia]

I either read on my Kindle or I faff about on Facebook or I might do my emails, or my bank... [Bethan]

By WhatsApp, by Messenger, by email, occasionally and by telephone. I prefer it when he rings on my landline so I can sit in comfort on my sofa and I can hear better. [Kelly]

Smart home technologies should promote and facilitate social inclusion by recommending social groups with similar interests. The participants suggested that smart home technologies might be useful to meet like-minded people. Older people need to feel confident, and “they have something of interest to say instead of talking about their illness all the time,” as 1 participant suggested:

...So, you could have maybe set up a group online of people in their 70s who live in this neighbourhood who have similar interests and you could maybe have a conference call or a virtual meeting for people who can’t get out, that would be very good...they’ve all got different likes, dislikes, so I think the smart home, it got to have some personal tweaks, it’s got to have a pick and mix maybe. One size doesn’t fit all, maybe. [Kelly]

Maybe you’ve had the experience of having elderly relations that can only talk about their illness...but so I think is really important that we’re still able to maintain a relationship with the world. So, in that way and by the fact that you are at least in regular contact with some people online, that helps to maintain your self-confidence, which is such an important part of actually reaching out to new people...it gives you things to talk about. [Alice]

However, 1 participant was resistant to the idea of contacting new people or joining new groups on the web.

**Enhancing Family Links**

Most participants were concerned that smart technologies might disturb social ties and emphasized that any new technology should enhance communication with relatives, friends, and neighbors:

The biggest concern for me is the human factor which might get stopped because of this technology. I mean so you know the children, the grandchildren they might not keep in touch with the parents. [Molly]

Communication topics varied largely because the participants wanted to share their life experiences with their family members. They mainly discussed childcare, family, work and health issues, and common passions such as gardening, birds, and hobbies:

We have a little family WhatsApp. So, we do often share something that will come up or they’ll send a picture. The other day, one of the children won a little football medal so, you know, it circulated and then we all chatted a bit about how proud we were and one thing and another. [Alicia]

Oh Jonny in America, oh how he is, one of my passions is square foot gardening and he does square foot gardening and I like to hear about that...[Christine]

Of the 13 participants, 12 (92%) participants described their neighborhood as safe and friendly. Few of them cited a good neighborhood as the reason for their lack of need for such a system, as discussed in the study by Ghorayeb et al [7].

**Enhancing Cognitive Abilities**

**Overview**

Most participants expressed worries about their cognitive faculties. They tried to use technology to improve their abilities by enrolling in educational courses, games, reading, and web-based activities. Smart home technologies can predict users’ activity quality and promote their cognitive health by reminding them or suggesting new ways based on their usual comportment.

**Cognitive Reminders or Enhancement**

The participants suggested that the smart home interface should remind them of the day and date, time, weather, temperature, bus timetable, bin collection schedule, appointments, the location of the wearable device (if not worn at the time), and the renewing time of nearly expired cards:

With older people, it might be useful, at some point, to know what the weather is like outside because I think that does affect what people do or wear...It would be really useful if it had something on it telling me where the wearable... [Bethan]
I’d quite like to know temperature change, that would be quite useful, times of the day, you know what sort of activity, intensity of activity, things like that would be quite useful...Power use, water use is quite interesting. [Edward]

...Remind him that he’s now six weeks before he’s 65, so he should apply for his bus pass...it would be better if like the news in the morning said...or something came up saying, “Good morning. It’s Tuesday,” because then you’ll think “Oh Tuesday, I...” [Bethan]

Smart home technologies should play a crucial role in enabling older people to monitor their daily activity levels, as this helps maintain health and achieve personal objectives. Maintaining an active lifestyle can help older people to prevent disease, lower the risk of falls, improve mental health and well-being, strengthen social ties, and improve cognitive function:

...It would be useful, at the beginning of dementia when you think you’ve got things but somebody says, “Well, actually, you didn’t turn the tap on all day today, so what have you been drinking?...chivvy them up and make sure they have a drink and whatever?”

Walking... [Bethan]

If you have the average levels of activity of all 70 other people that are involved or all the hundreds of people that are involved as a comparison. [Comparing between participants to challenge.] [George]

Visualizing a meaningful series of data would enable older people to see the utility of this technology as one participant explained:

I would adopt this technology if I could get a meaningful series of data, then I’d consider it probably being worthwhile. [Liam]

Enable Web-Based Learning, Cognitive Games, and Shopping

If older people have the opportunity to engage in activities and learn relevant skills, this may improve their efficacy and ability to live independently and reduce their risk of developing Alzheimer disease [41]. e-Learning and educational programs helped participants feel more confident, and brain exercises helped delay memory loss. Therefore, board games, crossword puzzles, reading and other types of web-based adult education classes, web-based shopping, memory games, or video games may help slow memory loss, improve daily tasks, and increase the ability to perform housework. This will also satisfy the learning and self-esteem needs of older people:

I’m very worried that I might get dementia. FutureLearn [web-based education classes], they’re usually three week, four weeks, six-week, eight week courses. So, for instance, I’ve done one about dementia, and I’ve done about 30 or 40 courses now, and they’re from all the different universities around the world and they’re free! [Bethan]

Also, I’m interested in languages. I have the iPad, I watch German television... [Daniel]

Watch TV, read a book, or sometimes even bake, looking for recipes... [Molly]

Newspapers and books, I’ve got loads, I haven’t read all of them...They’re all different sorts of books. [Christine]

There are several apps that I quite often look at chess problems. They’re quite good actually... [Daniel]

I get a newspaper and I walk back and drink my drink and do my Sudoku and things like that. [George]

Web-based shopping is gaining popularity among older people at an accelerating rate. To some extent, interest in web-based shopping for groceries or clothes is defined by older people’s knowledge and experience. Being confined to the home, some older people show interest in shopping for food and clothes on the web [42]:

Living in isolated communities, showing how to use the internet and particularly for older women, the first thing they want to do is to buy clothes online as it helps give them back their self-respect... [Alice]

Customizability of the Display

Overview

Older people should be given the option to select the features that they think they need or they like [7]. They should be able to select which data to visualize and who can access their data and when. The technology must be tailored to the person’s individual needs:

I think they need to be tailored to the individual person’s needs so you shouldn’t just have a one plan for everybody, although it’s smart technology it has to be tailored to the person’s individual needs...I think everybody now is gradually used to smart things in their homes, whether it’s their electricity meter or whatever, within the next five to ten years it will be normal to have certain...and I guess you could just extend that as you get older and more frail. [Izzy]

...I mean obviously we get our water bill so because we’re on a meter so we know what we’re consuming... [Florence; as she had a smart meter, she was not interested to visualize information about water or electricity consumption, and she wants to omit this feature]

I don’t want more technology than I need, you know; I don’t like excess technology. [Liam]

Well, only if they were useful. [Bethan; when asked about data to visualize]

Layout Consistency

Few participants stated that the display should conserve the same layout to keep them engaged, as changes to some social media displays caused them to disengage:

I have not used it much lately [about a social media tool]. I think they’ve changed the layout and I thought, oh, I can’t be bothered...I’d want to have a say in maybe designing and choosing what I’d have. [Kelly]
Some participants required the ability to add information, such as to inform friends or families that they would be away for a while:

...There should be a way to say, “Well, I’m, I’m not here for a week.” [Bethan]

Smart Home Friendly Behavior
Future systems should communicate information to older people in a friendly and easy-to-understand manner:

So, you know, I don’t want it to be too Big Brotherish but somehow... [Bethan]

...make it user friendly, make it a bit larger so they can get hold of it, because they’ve got problems or issues with their fingers and thumbs...make sure that it’s functioning... [Molly]

Promoting Inclusion in Recreation and Leisure Activities
Overview
Social inclusion is a complex concept for many older people, as it reflects their sense of belonging in a community where they can participate in activities based on their individual preferences. Smart home technologies should provide services and information that promote social inclusion and keep people active and occupied.

Old but Active: Exercises and Going Out
Coping with physical and emotional changes is particularly challenging for older people. From children moving away to the death of relatives or friends, declining health, and changes in lifestyle, participants tried to revive themselves by enjoying new things and learning to adapt to change. They tried to be involved in their community by attending local events or volunteering at different places and in different roles. They liked passing on their skills and helping other people. The participants felt young in their minds and kept themselves busy most of the week:

I don’t want to grow old being, you know, frightened of everything...Monday, Tuesday, Wednesday, Thursday, I go for a walk early with a friend who’s got a dog and Mondays and Fridays, I go to Zamba Gold and Tuesdays and Thursday, try and go to badminton and I try and make that, like, sacrosanct. I’m on several committees, so I go out on a regular basis; like once a month to this or twice a month to that; that sort of thing...I also do FutureLearn [web-based social learning platform]. [Bethan]

I walk a lot...I used to play tennis but I’ve got a bad shoulder, so I gave up...at the moment, I go quite often down to my allotment, so it’s either planting or picking... [Florence]

During the day, well I usually go out somewhere, yesterday I went to a meeting at the church, today I’m going to a lunch club. Tomorrow I’m probably going to do some shopping. Thursday I’m having my hair done and do a big shop and Friday I shall wait and see what I’m going to do. [Christine]

Through this study, we learned about the participants’ daily behaviors and activities. The interface should reflect their desire to lead active and engaged lives and be aligned with their self-views. Ageist attitudes are common in the community, and as age is a relative concept, we noticed that most of the participants would accept the technology much more if it did not treat them as “old”:

[When talking about his neighbor refusing to use monitoring technology] I think she thinks that it conflicts with her pride to be independent. She’s 97, you know! [Liam]

Volunteering Activities
Among other benefits, volunteering and being active can make older people feel better. It reduces stress, prevents loneliness, and improves mood. Volunteering allows older people to maintain their physical and mental health by keeping them physically and mentally active. Meaningful and productive activities can help older people feel happier and have a positive outlook on their lives:

I’m the Treasurer to two different organisations. I’m part of the Older People’s Forum. [Bethan]

I volunteer for about four different things. So, I volunteer at an international charity bookshop, half day a week. I befriend a refugee and her child, so I take them out and I visit them and so on. I volunteer at St. Georges which is a music venue...and I volunteer at a retirement home, I do a coffee morning and the poetry group. So that’s quite a regular thing. [Kelly]

I help out as a volunteer, trying to help people learn either rudimentary computer skills or how to use software that they have with phones and tablets and laptops and the other commitment I have in the course of a week is I have been spending a day or at least part of a day at a community farm, where we attempt to grow organic produce... [Henry]

I work with an organisation for retired people who like to provide something for the community, so I went down and volunteered at my doctor’s surgery and I started off a tea and talk club or something for people who live on their own...So we started off with about half a dozen people who, the volunteer drivers would pick up and bring them to the pub and we’d provide tea, coffee, cakes and talk once a month only about some of the things which they might be interested in, and then we started inviting more and more people...But now we’ve got 30 people and the people who identify the people who live on their own are the doctors and nurses in the surgery, so they are the ones who get in touch with them and after they’ve agreed that we can get in touch with them, then we’ll start ringing them up and provide this service. In the last four years we’ve realised that the visits they make to the doctor’s surgery have dropped! [Molly]
**My Buddy**

*My Buddy*, the in-home interface, was designed and developed by older people for older people. The design sessions were extremely beneficial for exploring the needs of users. During the brainstorming session, the idea of designing a new interface for older people became clearer and more concise. Consequently, they began to propose new functions and more intriguing features. They carefully chose the system functionalities they required (Figure 7).

On the primary smart home interface, the participants found it useful to have information about the wearable’s battery level, room temperature, weather and pollen level, date, and time. On the left side of the screen, participants recommended social and cognitive triggers. These triggers would be customized based on the user’s mood, health, and social status. The system may recommend a special diet, walk, web-based courses, or TV programs. They divided the reminders into 2 sections: one for “today events,” such as going to a movie or an appointment or taking medication and another for “tomorrow events,” such as “bin collection day” or an approaching appointment, allowing older people to get ready earlier. Given the weather and the advance reminders, older people can plan their trips. On the right side of the main display, older people can access their health information; specify their mood for the day; select a social activity; take care of their well-being; configure the system; or contact the assistant, dubbed *My Buddy* during the design sessions.

On the “health records” screen, participants desired access to their allergies, vaccinations, medications, and health records, including their cholesterol and blood sugar levels, weight, and blood pressure. They wanted the system to recommend activities and suggestions based on their “mood today.” Participants designed and drew 5 emojis to express their moods (Figures 6 and 7); therefore, this was not a standard scale of measurement. In their health records, participants wanted to view their current and historical blood pressure, cholesterol, blood sugar, and weight readings. They preferred customized recipes, diet advice, exercise, and consultations.

Social activities were categorized as either “local” or “going out” activities. The system may recommend web-based courses, games, meet-up groups, and recipes based on the users’ preferences, health status, and mood for the day. The “going out” option would provide the user with the ability to search for social events; nature walks or activities; sports; or “the suggestion of the day,” where the system will recommend daily events, such as knitting, dancing, and book clubs. The well-being feature would provide the user with healthy recipes, jokes, web-based exercises, and diet advice. If necessary, “Buddy my assistant” would enable the user to communicate with a health professional or technical support. The “setting up my machine” option will allow the user to customize the technology by adding or removing features, configuring data access permissions, turning the system on or off, and so forth.

**Discussion**

**Principal Findings**

There is a lack of research on what information older people would like to visualize and how to display it on a smart home interface [1,4,43]. Data visualization helps older people to make an informed decision about their self-care [18] and adopt smart home technology [1]. Visualized data can enable older people to self-monitor and understand and reflect on their own activities, allowing them to become more active and change their behavior. In addition, older people may become more active in monitoring their health or environment. In this study, we attempted to address this gap by understanding older people’s views of information and considering individuals’ experiences and cultures. The participants played an active role in developing and designing the in-home interface. As we started this project, we had no presumptions; rather, we sought to identify the information that older people would consider useful or vital to support their daily life activities and how they would like this information to be presented.

**Main Contributions and Links With Prior Work**

Although studies have investigated how collected data would be translated into data visualization, no research has focused on the information needs of older people [4]. This work supplements the existing literature by identifying the information that would enable older people to feel able to adopt smart home technologies and to visualize and access this information. The work described in this paper was informed by an earlier study [7] and individual interviews in which older people stated that smart home technology could be stigmatizing, could signify frailty, and should provide what they consider attractive and useful. Participants expressed an interest in technologies that provide customized group lessons, learning tools or classes, cognitive triggers and activities, social events, health and diet advice, and suggestions for connecting with like-minded people.

A well-designed visualization that translates collected data into a usable interface should promote active engagement of older people in health care and well-being and further social communication and activities. Participants found that the collected data and visualizations could be used mainly as prompts or triggers to enhance and provoke cognition.

Some participants were willing to share some visualizations with family members or health care professionals when needed while maintaining control over the transmitted data. Monitoring an individual’s health parameters can aid in early intervention and clinical decision-making [44]. The visualization should allow users to customize the system and gradually add features that respect their preferences and abilities as their needs evolve over time [7]. This was one of the findings of Castelli et al [25], who studied data visualization for people using smart homes, not just older people.

To improve the acceptability of smart home technology among older people, it is essential to raise awareness of its usefulness and emphasize its potential to promote independence, social interaction, and safety. It is vital to “enable the user to present the image that they want to convey to others” [45]. As discussed in our previous work [7], the in-home interface should provide
older people with control over transmitted data, such as the ability to turn off or temporarily pause the technology. Most participants wanted to select which data to visualize and when and who can view their data. It should provide access to their current and historical health-related data, as well as bus timetables, healthy recipes, and dietary advice. Participants wanted My Buddy to remind them to take their medications, as well as to provide advice related to the weather, their health status, and mood. In addition, they wanted to be able to play web-based games, access information about physical activities, and participate in gatherings and discussions with other older people. In our study, we did not suggest which data to visualize, as we prioritized the needs of the participants. Real-life metaphorical representations were suggested by users themselves. As seen in the study by Mynatt et al [24] and others [1,10,13], visualizations that are not co-designed with potential end users may be susceptible to information overload or a lack of understanding of data abstractions. For instance, 3 interactive interfaces provided by Reeder et al [3] were found to be difficult to use; the bar chart was challenging to interpret; and the use of color led some participants to experience visual discomfort. In the study by Jo et al [10], the display of an already designed interface of an air quality sensor was difficult to read and understand. In contrast, involving participants as designers helps to identify the right information to display, as shown in the work by Doyle et al [20], who developed a display based on the analysis of semistructured interviews with 7 older people. In their study, participants complained about the ambiguity of the displayed information and expressed the need for more information. This affects people’s ability to interpret data accurately [33]. Previous studies have demonstrated the potential of visualizations to affect health and well-being [2,24]. However, these studies typically did not provide participants with actionable recommendations to follow, which limited their ability to translate visualizations into meaningful behavior changes. Moreover, older people in these studies had difficulty interpreting the visualizations and translating them into actionable steps themselves [2]. In contrast, this study involved participants who not only proposed actions based on the observed data and trends but also designed the way in which these actions should be presented to the user. These recommendations on health, social, and physical activities are likely to have a positive impact on behavior and health outcomes. This “data-to-information-to-action” approach has been suggested to be particularly effective for older individuals [2].

In this analysis, we did not observe that experiences living in smart homes, educational level, and varying age affected the choices of interface design. However, the 2 participants who had no experience with mobile phones or social media technologies were among the participants who did not want to participate in the design workshop, which may highlight a need for future research to consider how best to include individuals with less experience of technologies.

**Design Insights**

In this study, participants designed the in-home interface, which they called My Buddy, by sketching the visual metaphors that they believed would make the tool meaningful and user-friendly. It is essential to use various research methods to uncover the requirements of older people. When asked in the interview, some older people described themselves as “healthy,” despite the activity using probes indicating that they had various chronic diseases. They did not consider themselves ill if they could perform their daily tasks independently. Thus, it was important for the design of My Buddy to reflect the multiple ways in which older people constructed their own health—as physical, social, and cognitive. Technology that isolated aspects of this would not be welcomed. In contrast, for instance, most of the participants used their smartphones for similar purposes, such as playing web-based games, sending or checking emails, reading the news, and searching for recipes or health-related information. They anticipated that the same functionality would be provided on the smart home display, but in a “smarter” manner, where the system recommended activities, diets, social events, or cognitive triggers based on user behavior and needs. Smart home technology should promote older people’s confidence, self-esteem, personal and social acceptance, and recognition of the contributions they made in their youth. Moving our starting point from “diagnosis” to empowerment reflects the participants’ own desires about the way to live their lives in the healthiest way possible.

Our study has shown that older people must be included in the analysis and design of their own in-home interface to incorporate their contextual knowledge, preferences, and needs. Co-design methods have been incorporated in many studies to investigate older people’s perceptions of smart home technologies. However, it may be time to consider older people as designers rather than simply informers. We suggest that it is always preferable to involve end users in the design of the new in-home interface, for instance, because graphics that a designer might use, such as pie and bar charts, may not be the most accessible to the population who will use the technology [2,28,29].

Older people are ideal co-designers for the creation of visual metaphors based on their own culture or experience, and their input enhances the production of user-friendly displays that enable older people to engage in social activities, communicate with family and friends, monitor health, seek assistance when necessary, and have the option to select and customize the data visualization.

**Limitations**

This study was limited by its duration and the number of users who were involved as participants. However, previous studies indicate that usability issues can be identified using a sample of 5 to 8 participants [46]. The iterative nature of our study and the details and depth achieved indicate that the findings are relevant and transferable. Future work could involve health care professionals and relatives of end users in the design process; investigate accessibility features, such as voice control and sound alerts; and explore the next steps in the design of the interface and evaluate such a system in situ. We would also encourage future research to consider how to maximize inclusion and diversity in the research design and potential participants, in terms of sociodemographic characteristics, ethnicity, sex, and gender, as well as the cognition and experience of...
technology. All these factors may influence design needs and engagement with displays and technology.

Conclusions

Smart home data visualization is essential for improving the acceptability and perceived utility of smart home technologies. To the best of our knowledge, this study is the first to address older people’s need for information and perspectives on smart home data visualization. To explore the information essential to supporting older people in their daily life activities and decision-making, we used a qualitative research approach with 13 participants as partners to design a user-friendly in-home interface. We conducted focus groups, semistructured interviews, home visits, and probe activities. From the thematic analysis of the collected data, we extracted key themes related to older people’s behaviors and interests, and these informed the design sessions. Presenting data to older people may offer them the opportunity to engage in social activities, make timely adjustments to their actions, contact relatives or friends, monitor their health status, and ask for help when needed.

Our work highlights key points for consideration when designing visualizations for older people, who were involved as co-designers in this study. The in-home interface was created by older people to present the data in an easy and meaningful way. Participants provided detailed feedback to guide improvements in the graphical user interface, content, and design changes to increase the usefulness of smart home technologies. They were interested in visualizing data about their health records and activity levels to control their blood pressure, cholesterol and blood sugar levels, pulse, and activity levels. They asked for results over time, which would help them to track any changes and to manage their lifestyle better. An in-home interface that offers people the chance to select the features needed; add further features in the future; visualize cognitive triggers and customized health, social, and diet advice; and offer communication and social engagement opportunities would be essential for future smart home technology adoption. Data visualizations should support their well-being by promoting social engagement, enhancing cognitive abilities, and enabling inclusion in recreation and leisure activities. Finally, our findings may be used to inform smart home technology developers and may apply well to other age groups. The results may increase the utility and the potential for acceptance and adoption of smart home technologies by older people.

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Data Availability

Anonymous data related to this study are available to bonfide researchers on request to the corresponding author. In keeping with the research ethics approval received, the data will be available until May 2028.

Authors’ Contributions

AG was responsible for the study design, data collection, evaluation, analysis, interpretation and conceptualization, funding acquisition, and writing of the original draft. RG-H contributed to the study design, funding acquisition, analysis, interpretation, and conceptualization, and review and editing of the draft. RC contributed to the study design, funding acquisition, review, and editing. All authors agreed to the submission of the final version.

Conflicts of Interest

None declared.

References


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Abbreviations

SPHERE: sensor platform for healthcare in a residential environment
A WeChat-based Intervention, Wellness Enhancement for Caregivers (WECARE), for Chinese American Dementia Caregivers: Pilot Assessment of Feasibility, Acceptability, and Preliminary Efficacy

Y Alicia Hong, PhD; Kang Shen, MS; Hae-Ra Han, PhD; Van Ta Park, PhD; Pramita Bagchi, PhD; Huixing Kate Lu, LCSW-C; Hsiaoyin Chen, LMSW; Judy Huei-yu Wang, PhD

1 Department of Health Administration and Policy, College of Public Health, George Mason University, Fairfax, VA, United States
2 School of Nursing, Johns Hopkins University, Baltimore, MD, United States
3 Department of Community Health Systems, School of Nursing, University of California San Francisco, San Francisco, CA, United States
4 Department of Statistics, George Mason University, Fairfax, VA, United States
5 Chinese Culture and Community Service Center, Inc, Gaithersburg, MD, United States
6 Department of Oncology, Lombardi Comprehensive Cancer Center, Georgetown University, Washington, DC, United States

Corresponding Author:
Y Alicia Hong, PhD
Department of Health Administration and Policy
College of Public Health
George Mason University
4400 University Dr. MS 1j3
Fairfax, VA, 22030
United States
Phone: 1 7039931929
Email: yhong22@gmu.edu

Abstract

Background: Chinese American family caregivers of persons with dementia experience high rates of psychosocial distress and adverse health outcomes. Due to their immigrant and minority status, they face substantial obstacles to care and support, including stigma and misperception of dementia, limited knowledge and use of welfare and services, and poor social support. Few interventions have been developed or tested for this vulnerable population.

Objective: This study aims to pilot-test the Wellness Enhancement for Caregivers (WECARE) intervention, a culturally tailored program delivered via WeChat, a social media app highly popular in the Chinese population. The 7-week WECARE was designed specifically for Chinese American dementia caregivers to improve their caregiving skills, reduce stress, and enhance psychosocial well-being. Feasibility, acceptability, and preliminary efficacy of the WECARE were assessed in this pilot.

Methods: A total of 24 Chinese American family caregivers of persons with dementia were recruited for a pre-post 1-arm trial of the WECARE. By subscribing to the WECARE official account, participants received interactive multimedia programs on their WeChat account multiple times a week for 7 weeks. A backend database automatically delivered program components and tracked user activities. Three online group meetings were organized to facilitate social networking. Participants completed a baseline and a follow-up survey. Feasibility was assessed by the follow-up rate and curriculum completion rate; acceptability was assessed by user satisfaction and perceived usefulness of the program; and efficacy was assessed with pre-post differences in 2 primary outcomes of depressive symptoms and caregiving burden.

Results: The intervention was completed by 23 participants with a retention rate of 96%. Most of them (n=20, 83%) were older than 50 years and the majority (n=17, 71%) were female. The backend database revealed that the mean curriculum completion rate was 67%. Participants also reported high rates of user satisfaction and perceived usefulness of the intervention and high ratings of weekly programs. The intervention led to significant improvement in participants’ psychosocial health outcomes; their depressive symptoms reduced from 5.74 to 3.35 with an effect size of $-0.89$ and caregiving burden decreased from 25.78 to 21.96 with an effect size of $-0.48$. 
Conclusions: This pilot study suggests that WeChat-based WECARE intervention was feasible and acceptable; it also demonstrated initial efficacy in improving psychosocial well-being in Chinese American dementia caregivers. Further research with a control group is needed to assess its efficacy and effectiveness. The study highlights the need for more culturally appropriate mobile health interventions for Chinese American family caregivers of persons with dementia.

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KEYWORDS
Alzheimer disease; dementia; caregiver; Chinese American; mHealth intervention; social media; WeChat; mHealth; mobile health; informal care; caregiving; family care; spousal care; minority; ethnic; cultural; Chinese

Introduction
The American population is rapidly aging and becoming more diverse. The number of adults aged 65 years and older is projected to increase from 16.9% in 2020 to 22% in 2050, and the proportion of racial and ethnic minorities is expected to grow from 38.4% in 2020 to 50.3% in 2045 [1]. Currently, there are 6 million persons with dementia and 19 million family caregivers of persons with dementia in the United States. These numbers are expected to double by 2050 due to aging of the population [2].

Family caregivers of persons with dementia face a myriad of challenges related to the length, complexity, and intensity of caregiving. As a result, they have reported high levels of physical and emotional stress [3,4], depression and anxiety [5-7], poorer quality of sleep [8,9], and poorer quality of life [10-12]. Some develop chronic conditions including impaired immune functions, hypertension, and coronary health diseases [13]. Despite high rates of psychosocial distress in dementia caregivers, the existing interventions for racial or ethnic minority dementia caregivers are rather limited compared to those available to the White population [14].

Asian Americans are the fastest-growing racial group with a growth rate of 88% from 2000 to 2020 [15]. Chinese Americans make up 23% of the Asian American population with nearly 70% of them being foreign-born [16]. To date, the literature on Chinese American dementia caregivers is limited and mostly descriptive. Available literature suggests that Chinese American dementia caregivers face triple challenges. First, their perceptions of dementia, appraisals of stress, coping, and help-seeking behaviors are shaped by Chinese cultural norms of “filial piety” and “family harmony” [17]. Caring for older family members is not only a sign of love and pride but also a moral obligation [18,19]. Adherence to such cultural values helps caregivers find positive aspects of caregiving and also leads to psychosocial stress when perceived performance or outcomes could not match their filial expectations [20,21].

Under the “family harmony” cultural values, caregivers are more likely to internalize stress and less likely to seek external help. Second, as most Chinese American family caregivers are foreign-born, their immigration status and unfamiliarity with the health care and welfare systems render limited knowledge and use of formal services [18,22,23]. Third, compared to long-time residents, first-generation immigrants have smaller social networks, less buffer zones, and limited social support. Chinese American family caregivers with limited English proficiency face additional linguistic and cultural barriers and are more socially isolated [24,25].

Despite these unique challenges and barriers, few caregiving interventions are tailored to the needs of Chinese American dementia caregivers [26]. In a recent review of global literature on existing interventions for Chinese dementia caregivers, only 2 were designed specifically for Chinese Americans [27]. One was a home-based behavioral management program and the other was a DVD-based psychoeducation program [28,29]. Both pilot interventions, developed by Gallagher-Thompson and colleagues [28,29] in early 2000s, cannot meet the current needs of Chinese American dementia caregivers. A strong need exists for easy-to-access and easy-to-scale mobile health (mHealth) intervention for this vulnerable population. This need has become more salient since the COVID-19 pandemic when in-person contact was restricted and the need for remote services was increasing.

Racial or ethnic minority populations are more likely to be smartphone-dependent for internet access (without computer or other mobile devices) and rely on social media as a primary source of health information [30]. With a 90% penetration rate in Chinese-speaking Chinese Americans, WeChat is the most popular social media app in this population [31]. The key functions of WeChat include “moments” for sharing photos and stories with friends and receiving “likes” and feedback, texting, voice call, video call, private chat, group chat, location sharing, file transfer, and payment. These built-in functions allow intervention developers to focus on program content rather than technical aspects of development maintenance, thus saving time and cost. It also enables easy adoption and long-term use, especially in populations with lower levels of health literacy [32]. Literature has shown the feasibility, acceptability, efficacy, and even long-term effectiveness of WeChat-based interventions in Chinese populations [33-36]. Thus, a popular and versatile social media app like WeChat could serve as a viable delivery channel for mHealth interventions to reach Chinese American dementia caregivers.

To address the literature gaps and public health needs of culturally tailored intervention for Chinese American dementia caregivers, we developed a WeChat-based intervention called Wellness Enhancement for Caregivers (WECARE) to address their psychosocial distress [37]. This paper reports the results from piloting WECARE, including its feasibility, acceptability, and initial efficacy.
Methods

Overview
This is a 1-arm, pre-post pilot trial. A total of 24 Chinese American dementia caregivers completed a baseline survey and received the 7-week WECARE intervention; their activities on WECARE were tracked by the backend database. Participants completed a follow-up survey 2 to 3 weeks after the intervention. Feasibility was assessed by the retention rate and curriculum completion rate. Acceptability was assessed by user satisfaction and perceived usefulness scale in the follow-up survey. Preliminary efficacy was evaluated by effect sizes of psychosocial health outcomes assessed at baseline and follow-up surveys.

Participation Eligibility
Participation eligibility included (1) self-identifying as Chinese or Chinese Americans and can read Chinese, (2) at least 21 years old, (3) currently living in the United States, (4) using WeChat, and (5) providing care at least 12 hours a week for a family member or loved one with Alzheimer disease, dementia, or other neurodegenerative conditions. Exclusion criteria included (1) being cognitively impaired or has serious mental health problems and (2) care partner has less than 6 months of life expectancy or in hospice care. When a potential participant contacted, our research staff conducted the screening. Those who met the participation criteria were invited to participate. A separate Zoom meeting was scheduled to obtain informed consent.

Recruitment
Participants were recruited from 2 sources. One was through our community partner, a community-based organization that serves Chinese Americans in the greater Washington, DC metropolitan. A recruitment flyer was distributed through social media and email newsletters. The other source was the University of California San Francisco Collaborative Approach for Asian Americans, Native Hawaiians, and Pacific Islanders Research Education registry [38]. Potentially interested participants contacted a designated phone number for more information and screening. Those who met the participation eligibility would learn more about the study and be invited to participate. A separate Zoom meeting would be scheduled for informed consent. Participants who completed the 7-week intervention plus the baseline and follow-up surveys would receive a gift card of US $100.

Ethics Approval
The study protocol was approved by the Institutional Review Board of George Mason University (IRB#1849712). All eligible participants had a one-on-one online meeting with a research staff who explained the study procedure and answered all questions. All participants provided verbal informed consent before they started the study.

WECARE Intervention
The 7-week WECARE intervention was developed to reduce caregiving burden, decrease distress, and enhance psychosocial well-being of Chinese American family caregivers of persons with dementia. Its protocol development and key features were detailed elsewhere [37]. By subscribing to the WECARE official account, participants would receive 6 multimedia articles on their WeChat accounts each week for the first 6 weeks and 4 in the final week for a total of 40 articles. Each week was focused on a theme. The seven major themes included (1) facts and knowledge of dementia and caregiving; (2) enhancement of caregiving skills; (3) effective communication with health care providers, care partners, and family members; (4) problem-solving skills for caregiving stress management; (5) stress reduction and depression prevention; (6) practice of self-care and health behaviors; and (7) social support and local resources. All multimedia articles required 3 to 6 minutes read time. Embedded in the articles were pictures, short video clips, and downloadable forms; all articles were culturally tailored for the target population and accompanied by audio recordings in case some older caregivers would prefer listening to audio recordings over reading texts. Three moderated group meetings were organized at weeks 3, 5, and 7 to facilitate social networking. Participants could also use the built-in functions in WeChat to initiate group chats, private chats, or video calls for additional networking and peer support. The official account of WECARE had a backend database that managed intervention delivery and tracked user activities [37].

Intervention Delivery and Data Collection Procedure
A total of 24 participants were enrolled in the study. After the informed consent, participants completed a web-based baseline survey and then subscribed to the WECARE official account via their WeChat app. WECARE automatically sent multimedia program components 4-6 times a week, at a prescheduled time Monday to Saturday, for 7 weeks. During the 7 weeks, participants’ activities on WECARE, including whether a program component was opened, how many times it was opened, and for how long, were tracked by the backend database. Participants who had not opened WECARE for a week would receive a friendly reminder via WeChat. Those who were not responsive to our reminders for 3 consecutive weeks were considered dropped out. A follow-up survey was administered 2 to 3 weeks after the intervention completion. Surveys were in Chinese, the links to the online surveys were sent to participants in their WeChat accounts or emails, and they could open the link in any browser.

Measurement

Overview
Two sets of data were collected in the pilot study: (1) baseline and follow-up surveys administered online before and after the intervention (see Multimedia Appendix 1 for complete baseline and follow-up surveys) and (2) user activities tracked by the backend databases (see Multimedia Appendix 2 for screenshots of WECARE frontend and backend). These data were used to assess the feasibility, acceptability, and initial efficacy of the WECARE intervention. Table 1 illustrates the domains of measures and data sources.
Table 1. Data sets and domains of measures.

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Baseline survey</th>
<th>Backend database</th>
<th>Follow-up survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retention rate</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Curriculum completion rate</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>User activities: total and weekly read counts; total and weekly reading minutes</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Acceptability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>User satisfaction</td>
<td></td>
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<td>✓</td>
</tr>
<tr>
<td>Perceived usefulness of WECARE(^a)</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Perceived usefulness of weekly program</td>
<td></td>
<td></td>
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<tr>
<td>Efficacy</td>
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<td></td>
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<tr>
<td>Depressive symptoms</td>
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<tr>
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<tr>
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<td>✓</td>
</tr>
<tr>
<td>Perceived social support</td>
<td></td>
<td></td>
<td>✓</td>
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</table>

\(^a\)WECARE: Wellness Enhancement for Caregivers.

Feasibility
Feasibility was measured by three indicators about how participants have completed the intervention trial: (1) retention rate was assessed by the percentage of participants who completed the follow-up survey. (2) Curriculum completion rate was assessed by the percentage of a participant’s completion of all 40 articles of the WECARE curriculum. For example, if a participant completed 20 articles, his or her curriculum completion rate was 50%. If an article was opened, it was considered read or completed, which was tracked by the backend database. We calculated the mean value of all curriculum completion rates of all participants. (3) User activity was assessed by read counts and reading minutes tracked by the backend database. A “read count” was the number of times a participant had opened an article; “weekly read count” was the sum of read counts on a week’s program; and “total read count” was the sum of all read counts. “Reading minutes” was the minutes a participant spent on an article; “weekly reading minutes” was the sum of reading minutes for a week’s program; and “total reading minutes” was the sum of all reading minutes. These indicators of user activity reflected user engagement.

Acceptability
Acceptability was measured by three indicators, all were drawn from our previous digital health intervention evaluation [39]. The first two were about their experience of the overall WECARE program; the last one was about each of the weekly program. (1) User satisfaction was assessed with a 7-item user-satisfaction in the follow-up survey on how participants liked the WECARE program, for example, “it was easy to use,” “it was fun to use,” and “I would recommend it to my friends or family.” Each question has response options from strongly disagree to strongly agree. The total score had a range of 5-35 with a higher score indicating a higher level of user satisfaction. The Cronbach \(\alpha\) for the scale was .737. (2) Perceived usefulness of WECARE was assessed with a 5-item scale in the follow-up survey on how participants perceived the WECARE intervention had helped them, for example, “become a better caregiver” and “learn more about stress management and mental health.” Each item has 5 response options from strongly disagree to strongly agree. The total score had a range of 5-25 with a higher score indicating a higher level of perceived usefulness. The Cronbach \(\alpha\) for the scale was .834. (3) Perceived usefulness of weekly program: The follow-up survey included questions asking participants how useful the weekly programs and moderated group meetings were. The response options ranged from not useful at all (1) to very useful (5). The mean score was calculated for each weekly program and the group meetings.

Intervention Efficacy
Intervention efficacy was measured by whether the 4 psychosocial health outcomes have meaningful effect sizes as a result of the intervention. The primary outcomes were depressive symptoms and caregiver’s perceived burden, and the secondary outcomes were life satisfaction and perceived social support. (1) Depressive symptoms were assessed by the Center for Epidemiologic Depression Scale (CES-D) 10-item [40]. Participants were asked to rate whether they experienced symptoms associated with depression the past week (0=no and 1=yes) with a total score ranging from 0 to 10 with a clinical cutoff point of 4 as an indicator of elevated depressive symptoms [41]. The CES-D has been used to monitor and identify trajectories of depressive symptoms and has been validated with Chinese populations [42,43]. In this study, the Cronbach \(\alpha\) for depressive symptoms at baseline was .809. (2) Caregiving burden was assessed by the Zarit Burden Interview (ZBI). The 12-item ZBI is one of the most reliable measures of caregiver burden in the literature. Each item has 5 response categories from “never” to “nearly always” with individual scores from 0 to 4 for each item [44]. Across the 12 items, the total ZBI score has a range of 0-48 with a cutoff point of 13 for
community-dwelling caregivers [45]. ZBI has been validated in Chinese populations [46,47]. The Cronbach α for ZBI at baseline was .824. (3) Life satisfaction was assessed by the Satisfaction With Life Scale (SWLS) [48]. The SWLS contained 5 items and used a 7-point Likert-type scale from 1 (strongly disagree) to 7 (strongly agree). The SWLS assessed the individual’s evaluation of his or her life by using the person’s own criteria (eg, “In most ways, my life is close to my ideal”). It has been validated in Chinese older adults and Chinese dementia caregivers [49]. The Cronbach α for SWLS at baseline was .915. (4) Perceived social support was assessed by a 10-item scale adapted from Social Support Scale (SSC). Validated in the REACH II study, this scale used a 4-point Likert scale from 0=never, 1=occasionally, 2=sometime, and 3=always to assess how often caregivers receive social support from family or friends [50]. The total score of social support ranged from 0 to 30 with a higher score indicating a higher level of social support. The Cronbach α for SSC was .756. 

Demographic Characteristics

Demographic characteristics of participants were assessed in the baseline survey. Caregivers’ characteristics assessed included age, sex, marital status, education, employment status, years of living in the United States, English proficiency, health status, and having difficulty paying for the basics. Care-partner characteristics assessed included age, sex, relationship to caregiver, living arrangement, and functional status measured by activity of daily living (ADL) [51] and instrumental activities of daily living (IADL) [52].

Statistical Analysis

First, descriptive statistics were used to describe the sample characteristics, feasibility and user engagement, acceptability, and user satisfaction. Cronbach α was used to calculate internal consistency of the scales. Then, paired t test was used to compare pre-post differences in efficacy measures of psychosocial health outcome; the statistical significance was set as P value ≤.10. Finally, given the small sample size, we calculated effect sizes for the health outcomes [53]. The small sample size also limited the power for stratified analysis, so we did not conduct multivariate analysis to examine the independent relationship between the outcome variables and independent variables such as demographics and user engagement. All analyses were conducted using Stata (version 14; StataCorp).

Results

Participant Characteristics

As shown in Table 2, a total of 24 participants were enrolled in the study, 71% (n=17) were female, and 88% (n=21) were married or living with a partner. Their ages ranged from 38 to 85 years, with 83% (n=20) were older than 50 years of age, and the mean age was 60 (SD 11.99) years. All participants were born in China and had lived in the United States for 23 years on average (ranged 3 to 44 years). About 54% (n=13) had limited English proficiency, and 46% (n=11) had difficulty paying for the basics. Many caregivers (n=16, 67%) were taking care of their parents or parents-in-law, 29% (n=7) were taking care of a spouse, and 1 was taking care of a friend. Care partners’ ages ranged from 60 to 91 years with a mean of 81 years. Care partners’ mean ADL score was 12 (ranged 0 to 27) and mean IADL score was 20 (ranged 7 to 24).
Table 2. Demographics of caregivers and care partners.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Caregiver (CG) (N=24)</strong></td>
<td></td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>59.58 (11.99)</td>
</tr>
<tr>
<td>Female sex, n (%)</td>
<td>17 (71)</td>
</tr>
<tr>
<td>Married or living with a partner, n (%)</td>
<td>21 (88)</td>
</tr>
<tr>
<td>Years of living in the United States, mean (SD)</td>
<td>23.4 (10.5)</td>
</tr>
<tr>
<td>Limited English proficiency, n (%)</td>
<td>13 (54)</td>
</tr>
<tr>
<td>Speaks Chinese or Mandarin at home, n (%)</td>
<td>22 (92)</td>
</tr>
<tr>
<td>Has difficulty paying for basics, n (%)</td>
<td>11 (46)</td>
</tr>
<tr>
<td><strong>Care partner (CP) (N=24)</strong></td>
<td></td>
</tr>
<tr>
<td>Age (years), mean (SD)</td>
<td>81.38 (8.65)</td>
</tr>
<tr>
<td>Female sex, n (%)</td>
<td>13 (54)</td>
</tr>
<tr>
<td>CP and CG live together, n (%)</td>
<td>16 (67)</td>
</tr>
<tr>
<td><strong>Relationship to CG</strong></td>
<td></td>
</tr>
<tr>
<td>Spouse, n (%)</td>
<td>7 (29)</td>
</tr>
<tr>
<td>Child, n (%)</td>
<td>16 (67)</td>
</tr>
<tr>
<td>Other relative or friend, n (%)</td>
<td>1 (4)</td>
</tr>
<tr>
<td>ADL\textsuperscript{a} score, mean (SD)</td>
<td>11.54 (9.47)</td>
</tr>
<tr>
<td>IADL\textsuperscript{b} score, mean (SD)</td>
<td>20.08 (5.64)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}ADL: activity of daily living.  
\textsuperscript{b}IADL: instrumental activities of daily living.

**Feasibility**

Three indicators were used to assess feasibility: (1) follow-up rate, (2) curriculum completion rate, and (3) user activities. Out of 24 participants who were enrolled at baseline, a total of 23 completed the intervention and follow-up survey, with a retention rate of 96%. The backend database revealed that out of the 23 participants in the follow-up, the curriculum completion rate ranged from 8% to 100% with a mean value of 67%. Participants’ total read counts of program components ranged from 5 to 154 with a mean of 54. Participants’ total reading minutes ranged from 1 to 7196 minutes with a mean of 465 minutes (see Multimedia Appendix 3 for a table on each participant’s read count, reading minutes, and completion rates). Out of 23 participants, 6 (27%) completed less than one-third of the WECARE program, 4 (17%) completed one-third to two-thirds of the program, and 13 (56%) completed more than two-thirds of the program, suggesting most participants had a high level of user engagement (see Multimedia Appendix 3).

**Acceptability**

Acceptability was assessed with four indicators, including (1) user satisfaction and (2) perceived usefulness of overall WECARE program, and (3) perceived usefulness and (4) user activity on the weekly program. Table 3 depicts user satisfaction of the WECARE program, and the mean total score was 32.52 out of the possible range of 5 to 35. Table 4 illustrates the perceived usefulness of the WECARE program, and the mean total score was 23.17 out of the possible range of 5 to 25. Table 5 details users’ perceived usefulness of each week’s program, and the score ranged from 4.35 to 4.65 out of a range of 1 to 5. Table 5 also lists the mean read counts and reading minutes by weekly program. The read counts for weekly program ranged from 6.5 to 10.6 times; the average total reading minutes of 23 participants for weekly program ranged from 40 to 132 minutes, with a big variation between weeks, see Multimedia Appendix 3 for mean weekly read counts and mean weekly reading minutes.
Table 3. User satisfaction (N=23).

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It was easy to use</td>
<td>4.87 (0.34)</td>
</tr>
<tr>
<td>2. It was useful for me</td>
<td>4.70 (0.47)</td>
</tr>
<tr>
<td>3. The time needed for the program was appropriate</td>
<td>4.65 (0.49)</td>
</tr>
<tr>
<td>4. It was boring to use (reversed score)</td>
<td>4.48 (0.95)</td>
</tr>
<tr>
<td>5. It was fun to use</td>
<td>4.48 (0.67)</td>
</tr>
<tr>
<td>6. I would recommend it to others</td>
<td>4.70 (0.47)</td>
</tr>
<tr>
<td>7. Overall, I’m satisfied with the program</td>
<td>4.65 (0.49)</td>
</tr>
<tr>
<td>Total score</td>
<td>32.52 (2.54)</td>
</tr>
</tbody>
</table>

Table 4. Perceived usefulness (N=23).

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. WECARE(^a) has helped me understand Alzheimer disease better</td>
<td>4.74 (0.45)</td>
</tr>
<tr>
<td>2. WECARE has motivated me to become a better caregiver</td>
<td>4.78 (0.42)</td>
</tr>
<tr>
<td>3. WECARE has helped me become a better caregiver</td>
<td>4.65 (0.49)</td>
</tr>
<tr>
<td>4. WECARE has helped me better manage stress and improve my psychosocial well-being</td>
<td>4.48 (0.67)</td>
</tr>
<tr>
<td>5. WECARE has helped me to better prepare the upcoming journey of caregiving</td>
<td>4.52 (0.51)</td>
</tr>
<tr>
<td>Total score</td>
<td>23.17 (1.99)</td>
</tr>
</tbody>
</table>

\(^a\)WECARE: Wellness Enhancement for Caregivers.

Table 5. Perceived usefulness and engagement by weekly program (N=23).

<table>
<thead>
<tr>
<th></th>
<th>Usefulness (range 1-5), mean (SD)</th>
<th>Read counts by week, mean (SD)</th>
<th>Reading minutes by week, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Week 1: Dementia facts and knowledge</td>
<td>4.52 (0.59)</td>
<td>10.6 (8.03)</td>
<td>132.1 (465.15)</td>
</tr>
<tr>
<td>2. Week 2: Caring for patients with dementia</td>
<td>4.65 (0.49)</td>
<td>8.3 (5.89)</td>
<td>113.5 (400.76)</td>
</tr>
<tr>
<td>3. Week 3: Effective communication</td>
<td>4.43 (0.66)</td>
<td>7.3 (6.46)</td>
<td>22.5 (31.38)</td>
</tr>
<tr>
<td>4. Week 4: Problem-solving in caregiving</td>
<td>4.35 (0.65)</td>
<td>7.1 (5.53)</td>
<td>40.4 (118.16)</td>
</tr>
<tr>
<td>5. Week 5: Stress reduction and depression prevention</td>
<td>4.35 (0.65)</td>
<td>8.7 (7.15)</td>
<td>49.3 (135.38)</td>
</tr>
<tr>
<td>6. Week 6: Becoming a healthy caregiver</td>
<td>4.39 (0.72)</td>
<td>6.5 (5.88)</td>
<td>40.3 (126.20)</td>
</tr>
<tr>
<td>7. Week 7: Course summary and local resources</td>
<td>4.57 (0.59)</td>
<td>8.2 (5.48)</td>
<td>66.5 (210.90)</td>
</tr>
<tr>
<td>8. Three group meetings online</td>
<td>4.39 (0.78)</td>
<td>__(^a)</td>
<td>__</td>
</tr>
</tbody>
</table>

\(^a\)Not available.

**Preliminary Efficacy**

The intervention efficacy was assessed with pre-post differences of 4 psychosocial outcomes: depressive symptoms, caregivers’ burden, life satisfaction, and social support. Table 6 lists the results of the pre-post differences and effect sizes of these measures. Despite a small sample size, 3 out of 4 outcomes had statistically significant differences. Specifically, depressive symptoms decreased from 5.74 at baseline to 3.35 at follow-up; the effect size was −0.89. Caregiving burden decreased from 25.78 to 21.91, and the effect size was −0.48. Life satisfaction increased from 11.35 to 14.83, and the effect size was 0.55. However, there was no significant change in social support.
Table 6. Caregivers’ psychosocial well-being pre- and postintervention comparison (N=23).

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Baseline, mean (SD)</th>
<th>Follow-up, mean (SD)</th>
<th>Change, mean (95% CI)</th>
<th>Effect size</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depressive symptoms (range 0-10)</td>
<td>5.74 (2.56)</td>
<td>3.35 (2.72)</td>
<td>−2.39 (−3.56 to −1.23)</td>
<td>−0.89 (−1.37 to −0.40)</td>
<td>&lt;.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Caregiving burden (range 0-48)</td>
<td>25.78 (7.19)</td>
<td>21.91 (6.69)</td>
<td>−3.87 (−7.38 to −0.36)</td>
<td>−0.48 (−0.90 to −0.04)</td>
<td>.03&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Life satisfaction (range 0-30)</td>
<td>11.35 (6.66)</td>
<td>14.83 (7.11)</td>
<td>3.48 (0.73 to 6.23)</td>
<td>0.55 (0.10 to 0.98)</td>
<td>.02&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Social support (range 0-30)</td>
<td>14.78 (5.15)</td>
<td>13.96 (6.39)</td>
<td>−0.83 (−3.39 to 1.74)</td>
<td>−0.14 (−0.55 to 0.27)</td>
<td>.51</td>
</tr>
</tbody>
</table>

<sup>a</sup>P<.005.<br><sup>b</sup>P<.05.<br><sup>c</sup>P<.01.

Discussion

Principal Findings

Our data strongly suggest that WECARE was a feasible and acceptable intervention in Chinese American dementia caregivers; it also demonstrated preliminary efficacy in improving participants’ psychosocial well-being. First, the intervention was feasible. A total of 24 participants enrolled in the study and 23 completed the intervention with a retention rate of 96%. The backend database that tracked user activities showed that the mean curriculum completion rate was 67%; in other words, on average participants had completed 67% of all 40 multimedia papers in the 7-week program. The mean read counts was 57, and the mean total reading minutes was 465 minutes, suggesting a good level of user engagement. Second, the intervention had good acceptability. The follow-up survey indicated that participants reported high levels of user satisfaction (32 out of 35), high levels of perceived usefulness of the intervention (23 out of 25), and high levels of perceived usefulness of weekly programs (4.3-4.5 out of 5). Third, the intervention demonstrated preliminary efficacy. The pre-post analysis of psychosocial outcomes revealed that, despite a small sample size, 3 out of 4 health outcomes, that is, depressive symptoms, caregivers’ burden, and life satisfaction, had statistically significant changes after the intervention, and the effect sizes ranged from 0.55 to 0.89. However, perceived social support for caregiving remained unchanged.

Data Interpretation

To the best of our knowledge, the WECARE represents the first mHealth intervention for Chinese American dementia caregivers and one of the first for immigrant and racial minority dementia caregivers. The results from the trial were comparable to earlier in-person interventions for Chinese American dementia caregivers [28,29] and other in-person interventions for other racial or ethnic minority dementia caregivers [54,55]. It is worth noting that the demographic characteristics of the participants in this study were comparable to earlier community-based studies on Chinese American dementia caregivers [21,29]. As underserved Chinese American dementia caregivers have high rates of psychosocial distress due to high intensity, duration, and complexity of caregiving, the success of the WECARE suggests a promising solution to deliver effective mHealth interventions to address the needs of this vulnerable group.

The feasibility, acceptability, and initial efficacy demonstrated in this study could be attributed to the following strengths of the WECARE. First, the curriculum of the WECARE was developed based on evidence-based interventions [50,56]. Second, the culturally tailored program components were developed using community-engaged user-centered design principles [57]. We worked closely with our community partners through an iterative process of design, test, and revise. The resulting WECARE program consists of 40 interactive multimedia articles that reflect Chinese American family values and social norms of caregiving; it also includes relevant information and resources urgently needed by these linguistically isolated caregivers. Third, the WECARE was delivered via WeChat, a popular social media app used frequently by participants; it was easy to adopt for continuous use [37].

We noted that despite significant improvement in 3 out of the 4 health outcomes (depressive symptoms, caregiving burden, and life satisfaction), participants still reported high levels of depressive symptoms (mean 3.35) and caregiving burden (mean 21.91) at the follow-up, suggesting elevated psychosocial distress despite the intervention. More resources and continuous support are needed to meet the needs of this vulnerable population.

One of the 2 secondary outcomes for efficacy evaluation, perceived social support for caregiving, did not change significantly after the intervention. There were 2 possible explanations. One, it might be that the sample size was too small to detect the change. Two, the WECARE had minimal effect on improving perceived social support in caregiving, even though 3 moderated online meetings were organized and participants could use the built-in functions in WeChat like group chat and private chat to initiate additional contacts. Social support requires long-term trust building and tangible support to address daily needs. A 7-week online program with limited interactions might not be the most effective approach to improve social support.

An important feature of the WECARE was its backend database that automatically sent program components and tracked user activities, including whether and when an article was opened, how many times it was read, and for how long. User activity data such as curriculum completion rate, total read counts, and total reading minutes could be used as objective measure of user engagement. These data also complemented the self-report survey data on user satisfaction and perceived usefulness to provide a more comprehensive understanding of the program’s...
feasibility and acceptability and inform further revision of the intervention. For example, high levels of user engagement tracked by the backend database and high levels of perceived usefulness reported in the follow-up survey for a particular week’s program might indicate its good acceptability; otherwise, it might suggest the need for further revision.

**Limitations**

This pilot study has several limitations. First, there was no control group, so we could not affirm whether the changes in health outcomes observed in this pre-post trial were a result of the intervention only instead of testing effects or other factors. The main purpose of the pilot study was to assess the feasibility, acceptability, and preliminary efficacy of the WECARE; thus, future research would need to test its efficacy through a rigorous randomized controlled trial. Second, all acceptability measures and health outcome measures were based on self-report, there were potential self-report biases. Third, the follow-up survey was administered 2-3 weeks after the intervention, so we were not able to observe the long-term effect of WECARE. A future study with long-term follow-ups is needed. Fourth, though the intervention retention rate was 96% with only 1 participant dropped out, the curriculum completion rate was suboptimal with 67%, suggesting some participants stayed in the intervention but did not complete the entire curriculum. However, these numbers were higher or comparable to other mHealth interventions for caregivers or other WeChat-based interventions [35,36]. Fifth, our sample size was rather small, so we were not able to perform any stratified analysis or examine the independent relationships between the intervention effects and key covariates such as demographics and user engagement, for example, if the intervention was more effective in some demographic groups. A future study with a larger sample size would be able to address this limitation.

**Conclusions**

The WECARE pilot study demonstrated that this WeChat-based intervention demonstrated a high level of feasibility and acceptability; it also showed promising efficacy in improving psychosocial well-being in Chinese American family caregivers of persons with dementia. It reduced participants’ depressive symptoms, decreased caregiving burden, and increased life satisfaction but had no effect on perceived social support for caregiving. Our next step is to conduct a randomized controlled trial with a larger sample and long-term follow-up to further test WECARE’s efficacy and effectiveness. Based on the promising results from this study, we call for more research on culturally tailored and digitally delivered interventions for immigrant and racial or ethnic minority family caregivers of persons with dementia.

**Acknowledgments**

The study was funded by the Virginia Center for Alzheimer’s and Related Diseases Research Award Fund (PI: YAH). We thank Chinese Culture and Community Service Center, Inc for tremendous support in participant recruitment and WECARE program design and evaluation. Some participants were recruited with support from the Collaborative Approach for Asian Americans, Native Hawaiians and Pacific Islanders Research and Education (CARE), which is funded by the National Institute on Aging of the National Institutes of Health (R24AG063718, PI: VTP).

**Data Availability**

This pilot study has a sample size of 24 only, and all participants were underserved Chinese American dementia caregivers. Even deidentified day poses potential risks of tracing back to some participants. Per our institutional review board requirement, we do not submit the data to a repository. Any fellow researcher interested in this data set may contact the corresponding author directly.

**Conflicts of Interest**

None declared.

**Multimedia Appendix 1**

WECARE project baseline and follow-up survey.

[PDF File (Adobe PDF File), 203 KB - aging_v61e42972_app1.pdf]

**Multimedia Appendix 2**

WECARE intervention frontend and backend screenshots.

[PDF File (Adobe PDF File), 439 KB - aging_v61e42972_app2.pdf]

**Multimedia Appendix 3**

User activities tracked by the backend database.

[DOCX File, 17 KB - aging_v61e42972_app3.docx]

**References**

https://aging.jmir.org/2023/1/e42972


15. Asian Americans are the fastest-growing racial or ethnic group in the U.S. Pew Research Center. 2021. URL: https://www.pewresearch.org/fact-tank/2021/04/09/asian-americans-are-the-fastest-growing-racial-or-ethnic-group-in-the-u-s/ [accessed 2023-03-02]


Abbreviations

ADL: activity of daily living
CES-D: Center for Epidemiologic Depression Scale
IADL: instrumental activities of daily living
mHealth: mobile health
SSC: Social Support Scale
SWLS: Satisfaction With Life Scale
WE CARE: Wellness Enhancement for Caregivers
ZBI: Zarit Burden Interview

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Usability of a Community-Based Dementia Resource Website: Mixed Methods Study

Missy Thomas1,2, BID, MDes; Dean Henderson3, BKin, MSc, MBA; Chantal Trudel1,2, BPH, BID, MSc; Neil Thomas2,4, MSc, MD

1School of Industrial Design, Department of Engineering and Design, Carleton University, Ottawa, ON, Canada
2Bruyère Research Institute, Ottawa, ON, Canada
3The Dementia Society of Ottawa and Renfrew County, Ottawa, ON, Canada
4Department of Medicine, University of Ottawa, Ottawa, ON, Canada

Corresponding Author:
Neil Thomas, MSc, MD
Bruyère Research Institute
43 Bruyère Street
Ottawa, ON, K1N 5C8
Canada
Phone: 1 1 613 562 6262 ext 4071
Email: nthomas@bruyere.org

Abstract

Background: Many individuals living with dementia want to live in their own homes for as long as possible. To do so, they frequently require assistance with activities of daily living, which is often provided by friends and relatives acting as informal care partners. In Canada, many informal care partners are currently overworked and overwhelmed. Although community-based dementia-inclusive resources are available to support them, care partners often struggle to find them. Dementia613.ca was created to make the process of finding community dementia-inclusive resources simpler and more straightforward by bringing them together in one eHealth website.

Objective: The objective of our study was to determine if dementia613.ca is meeting the goal of connecting care partners and persons living with dementia to dementia-inclusive resources in their community.

Methods: A review and assessment of the website was conducted using 3 evaluation methods: web analytics, questionnaires, and task analysis. Google Analytics was used to collect data related to website use over a 9-month period. Data on site content and user characteristics were collected. Furthermore, 2 web-based self-administered questionnaires were developed: one intended for care partners and persons living with dementia, and the other intended for businesses and organizations interested in serving persons living with dementia. Both gathered data on user characteristics and included standard questions used in website evaluations. Responses were collected over a 6-month period. Scenarios, tasks, and questions were developed for the moderated, remote, and task-analysis sessions. These tasks and questions determined how effectively persons living with dementia and their care partners can use dementia613.ca. Overall, 5 sessions were held with persons experiencing moderate cognitive decline and with care partners of persons living with dementia.

Results: This evaluation showed that the idea behind dementia613.ca is strong and appeals to persons living with dementia, their care partners, and the businesses and organizations serving this market. Participants indicated that it is a useful community resource that meets a previously unfulfilled need in the area, and highlighted the benefits of bringing community resources together on 1 website. In our questionnaire, >60% (19/29, 66%) of people living with dementia and their care partners and 70% (7/10) of businesses and organizations agreed that the website made it easier to find relevant dementia-inclusive resources. There is room for improvement; participants indicated that the navigation and search features could be further developed.

Conclusions: We believe that the dementia613.ca model could be used to inspire and guide the creation of dementia resource websites in other regions in Ontario and beyond. The framework behind it is generalizable and could be replicated to help care partners and persons living with dementia find local resources more easily.

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KEYWORDS
dementia; caregivers; eHealth; community resources

Introduction

Background

In 2020, it was estimated that 597,300 Canadians were living with dementia [1]. As of 2021, there are an estimated 36,991,981 Canadians, meaning that approximately 1.6% of the population is living with dementia [1,2]. The number of Canadians with dementia will continue to rise, with 78,600 new cases being diagnosed every year in Canada [3]. By 2030, the number of people living with dementia in Canada is projected to be close to 1 million [1].

Most persons living with dementia want to live in their own homes for as long as possible, and approximately 61% of persons living with dementia in Canada are able to live at home [4,5]. Those living with dementia at home frequently require assistance with activities of daily living, which is often provided by their friends and relatives acting as informal care partners [1,6]. In Canada, informal care partners spend an average of 26 hours a week supporting their loved one with dementia [7]. Many care partners are currently either overworked or overwhelmed. The Change Foundation’s 2019 Spotlight on Caregiving Report [8] presents current data on the well-being of care partners, and many are struggling with this role. The report noted that 75% of care partners wished that there was somewhere they could go for advice. In addition, >45% of care partners of older adults with dementia exhibit symptoms of emotional distress, which is almost double the number of care partners of older adults without dementia [7].

To maintain a good quality of life, persons living with dementia must engage in physically [9] and mentally stimulating activities [9] and avoid social isolation [10]. A lack of these enriching experiences can lead to boredom, which is linked to anxiety, apathy, wandering, and agitation [11], and contributes to many of the “challenging” or “difficult” behaviors associated with dementia [12]. It can also be challenging for already overwhelmed care partners to determine the best way to provide these activities. With the many community-based dementia-inclusive resources that are available, finding the appropriate ones can be difficult or even overwhelming for care partners who are already managing multiple tasks.

Currently, there are few community-based platforms with organized and reliable information regarding dementia-inclusive resources in an easy-to-search place [13]. Web-based resource directories could provide this service and transform how persons living with dementia and care partners access information regarding community resources. Although some studies have evaluated projects that aim to connect persons with dementia and care partners with information regarding community resources [14,15], there is a lack of web-based Canadian dementia-friendly resource directories.

The website, dementia613.ca, was created to make the process of finding community dementia-inclusive resources simpler and more straightforward by bringing them together in one website. The “613” in the name of the site refers to the area code for the greater Ottawa area. Before its launch, there was no similar directory in the Ottawa and Renfrew County areas. This website was created through a partnership between The Dementia Society of Ottawa and Renfrew County (DSORC) and the Bruyère Research Institute, supported by funding from the Centre for Aging and Brain Health Innovation Spark program. There were 3 distinct phases involved in the development of dementia613.ca: phase 1, obtaining end user feedback to guide website development; phase 2, low-fidelity prototyping and participatory evaluation and design development; and phase 3, launch and evaluation. This study focuses on the third phase.

The Creation of Dementia613.ca

Input from care partners and other stakeholder groups (eg, individuals with cognitive impairment, clinicians, and DSORC staff member) was sought during the entire design and development process. During the first phase of this project, held before the development process began, stakeholders were invited to participate in a web-based questionnaire to help inform website content and development. It was promoted to memory clinic physicians, as well as DSORC staff members, volunteers, and clients. The questionnaire included 17 questions, and responses were collected using a mixture of open-ended prompts and Likert-type scales. It gathered data on the participants’ characteristics, the types of information they wanted the website to contain, and suggestions for ease of use. Responses informed and guided website development and were referred to throughout the development process. The complete questionnaire and all the collected responses are shown in Multimedia Appendix 1. The questionnaire was available in English and all 46 respondents who started the questionnaire completed it. Most respondents identified as woman (37/46, 80%) and were aged between 45 and 64 years (25/46, 54%). Half of the respondents (23/46, 50%) identified their role as being a care partner for individual living with memory difficulties or dementia.

On the basis of the feedback gathered from these stakeholders, a website format was selected; searching on the internet was the second most common method for finding dementia-related resources. In addition, the questionnaire results indicated that the website should be mobile friendly so that it could be easily accessed on multiple types of devices. Several stakeholders indicated that they preferred to directly call the DSORC to receive information regarding resources. However, this service is only available during business hours. Stakeholder feedback provided evidence that creating a searchable web-based directory to bring existing resources together would provide a valuable service.

The second phase of this project, the development and design of the website, involved 2 rounds of participatory design testing, using 2 distinct methods. In both rounds, wireframe mock-ups of the website were created, and the participants were asked to complete simple tasks and provide feedback. Between rounds,
the website design was refined, and after the second round, the final design was reached.

The first round involved unmoderated, remote tree testing. It focused on testing the overall ease of use of the website’s navigation structure and how easily the information could be found. The participants completed a series of simple tasks and questions to evaluate their ability to follow the proposed navigation logic of the website. A total of 83% (25/30) of individuals completed the study (of the participants who started the study). This round of testing was conducted for 2 weeks in May 2020. The results indicated that the overall navigation structure was efficient, and only minor adjustments were needed where participants struggled. The second round of testing involved live one-on-one task-analysis sessions. This study focused on testing the ease and efficiency of its use. During the sessions, participants were asked a series of questions and navigated the wireframe to find answers. In total, 5 individuals participated in this round of testing for over 1 week in June 2020. The results indicated that users had trouble finding and using the filter-and-sort functions of the website.

On the basis of the results of the second phase, the main features incorporated into dementia613.ca included web-based filtering tools for finding relevant resources from the database with a category search and map view, organizational listings that included specific environmental features to help users better plan a visit, information for businesses about training to become dementia-inclusive, and the ability for organizations and businesses to submit a request for their resources to be considered for inclusion on the website.

The dementia613.ca website is also fully bilingual, available in French and English, because approximately 16% of Ottawa’s population and approximately 5% of Renfrew County’s population is primarily French speaking [16].

Goal of This Study

With the launch of dementia613.ca, this project entered its third phase, which is the focus of this study. We wanted to determine if dementia613.ca meets its goal of connecting care partners and persons living with dementia to dementia-inclusive resources in their community. The specific objective of our analysis was to evaluate feedback obtained from website users on the utility of dementia613.ca. Thus, a review and assessment of the website is required. In this paper, we present the findings from the multiple evaluation methods used during this phase, including data from web analytics, a questionnaire, and task analysis.

This study focused on evaluating website user demographics, reasons for website use, website use characteristics, and suggestions for ongoing improvement of the website.

Methods

In phase 3 of this project, several methods were used to evaluate the launch of dementia613.ca. This included web analytics, self-administered questionnaires, and task analysis.

Web Analytics

Google Analytics was used to collect data related to website use [17]. We collected information regarding the number of individuals who used dementia613.ca: the number of sessions (ie, the period in which a user is actively engaged with the website) that have occurred since the launch of the website; as well as demographic information regarding the visitors, geographic locations of the visitors, the frequency of the sessions, when the sessions occurred, and the top site contents viewed. Google Analytics was used to collect information from January 2021 to October 2021.

With regards to web analytics, a “session” refers to the time period users are actively engaged with the website from when they click on the link to enter the site, to when they exit the site; it includes all and any form of interaction (eg, viewing the screen or scrolling through pages on the website) per session by a single user. A page view is the number of pages viewed by a user, and the repeated views of a single page are counted.

Self-administered Questionnaires

A total of 2 web-based, self-administered questionnaires were developed, one was intended for care partners and persons living with dementia and the other was intended for businesses and organizations interested in serving persons living with dementia. Both gathered data on users’ characteristics and included standard questions used in website evaluations. The questionnaires were reviewed and piloted internally by hospital colleagues who did not have background information on the website evaluation project.

The version for individuals collected general demographic information regarding the individual, such as gender, age, and role (role options included individual living with memory difficulties or dementia, care partner to an individual living with memory difficulties or dementia, individual who works with persons living with dementia, health care professional or other). The version for organizations collected information such as organization type and number of employees. Both versions of the questionnaire assessed satisfaction with the design, content, and navigation of the website; frequency of use; users’ perceived trust of the information; and future intentions. Responses to the questions were acquired using a Likert-type scale. In addition, there were open-ended questions for additional comments regarding the website, including reasons for use and features that users would like to see added. The complete questionnaires are shown in Multimedia Appendices 2 and 3. Both questionnaires were developed to align with others in the literature, including evaluation of eMentalHealth.ca by Jeong et al [18]. The questionnaire used in that study was based on the Commission of the European Communities’ quality criteria for health-related websites [19]. In addition, questions were added to both versions of the questionnaire to ensure that they addressed the 7 categories in the User Experience Honeycomb developed by Peter Morville [20,21], that is, useful, valuable, usable, credible, accessible, desirable, and findable. The questionnaires were customized for this study, including questions regarding the specific and unique features of the design, such as map and search functionality. Finally, the questionnaire was developed to align with previous work done.
in phases 1 and 2, including questions that followed up on the topics of ease of use and relevancy of information.

Questionnaire responses were collected over a 6-month period, from January 2021 to July 2021. The questionnaire was made available through a link on dementia613.ca from March 2021 to July 2021 in both French and English languages. The questionnaire was promoted on posters displayed in a Geriatric Day Hospital and Memory Clinic and in the Dementia Society Monthly Newsletter. It was also sent to the Champlain Dementia Network, a collection of organizations that support persons living with dementia, to share among their networks. To encourage participation, a draw for gift cards was done over an 8-week period.

Task Analysis
The testing team developed a scenario, tasks, and questions for a moderated, remote, task analysis session to be held with persons experiencing moderate cognitive decline and the care partners of persons living with dementia. These tasks and questions aimed to determine how effectively persons living with dementia and their care partners could use dementia613.ca. The methods and sample sizes used to evaluate dementia613.ca aligned with the best practices in usability testing. To reach close to the user testing’s maximum benefit:cost ratio, it is standard to perform the test with 5 users per round [22-24]. This allows for multiple rounds of testing on iterations of the application, allowing designers and developers to identify and fix problems and then test the redesigned versions [25].

Tasks were created to test the 2 main features of the website (ie, web-based filtering tools and organizational listings with detailed information). The tasks centered on participants finding resources using the categories in the directory and using the map view to find resources near them. Participants who were not located in the Ottawa or Renfrew County areas were asked to complete the tasks assuming that they lived in downtown Ottawa. The tasks were based on 7 categories in User Experience Honeycomb by Morville [20,21]. To drill deeper into issues of accessibility, questions were also developed to determine whether the site content aligned with Web Content Accessibility Guidelines 2.1 [26]. Questions were designed to reach at principle 1: perceivable and principle 3: understandability [26].

The tasks and questions were reviewed and piloted internally by DSORC colleagues who did not have background information on the website evaluation project. The participants were recruited from the DSORC mailing list. The list included persons experiencing cognitive decline, current and former care partners, and DSORC dementia care coaches. Between March 3, 2021 and March 15, 2021, five task analysis sessions, with one participant per session, were conducted. They were conducted remotely over Zoom (Zoom Video Communications, Inc) and video recorded. The participants took varying levels of experience with dementia613.ca; 3 of them had never used the site and the remaining 2 had. Sessions took between 30 and 40 minutes to complete and started with the participant accessing dementia613.ca from their own laptop or tablet and screen sharing their view with the moderator. The moderator started the task analysis by describing the scenario to the participant and then asked them to complete a series of tasks and respond to the questions. Although there were multiple ways to complete the tasks, they did have the correct end state. As such, they were marked “complete” or “incomplete” in the analysis. The time taken by each participant to complete each task was recorded. The questions were open-ended, asking about participants’ opinions and beliefs regarding the tasks and the experience of using dementia613.ca. The responses were analyzed thematically using categories from the User Experience Honeycomb of Morville [20,21].

In this scenario, participants were asked to imagine that their relatives had recently been diagnosed with dementia. The participant knew that over time, their relatives’ care needs will increase, and so the participant wanted to learn more regarding local organizations and businesses that were dementia inclusive. They planned to do this using the website dementia613.ca. For the first task, participants started on the dementia613.ca home page and were asked to find information regarding courses or programs related to the arts and crafts. The correct end-state for this task was navigating to the categories Fitness, Exercise & Learning. During the second task, the participants were asked to determine which listings were close to their location. To do this, they had to select See Map View and navigate the provided map. In the third task, the participants were asked to obtain more detailed information on an individual resource. To do this, they had to click on an individual resource, which took them to the resource’s full listing page. For the final task, participants were asked to find information regarding the organizations that run dementia613.ca. The correct end-state for this task was to find and select the About link. After completing the tasks, the participants were asked 4 follow-up questions to examine their overall impressions.

Ethics Approval
The ethics application was submitted to and approved by The Bruyère Research Institute Ethics Board (# M16-19-042).

Results

Web Analytics
Between January and October 2021, Google Analytics reported 3924 sessions and 11,127 page views of dementia613.ca. The average length of each session was 1:40 minutes, and during that time, each user viewed an average of 2.84 pages. The list of Resource Categories and the French version of the site were among the top 5 viewed site features. Tables 1 and 2 and Textbox 1 summarize the web analytics collected via Google Analytics.

The vast majority of users (3143/3453, 91.02%) were new to dementia613.ca. More than two-thirds (2326/3453, 67.36%) were Canadian, and more than one-third (1212/3453, 35.1%) were located in Ottawa, Ontario. Approximately 10% (258/3453, 7.47%) were located near Ottawa, such as Gatineau, Quebec, and Ashburn, Ontario. This means that <45% (1470/3453, 42.57%) of users were in relevant locations.

Most users (62/74, 84%) accessed the website using desktop computers. In most sessions, users (2402/3924, 61.21%) reached the website directly. In other sessions, users (736/3924, 18.76%)
reached the website with a referral, of which dementiahelp.ca, facebook.com, and bruyere.org were the 3 most common websites.

Table 1. General Google Analytics data collected from dementia613.ca from January to October 2021.

<table>
<thead>
<tr>
<th>Analytic</th>
<th>Data collected from dementia613.ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timeframe</td>
<td>January 21, 2021 to October 28, 2021</td>
</tr>
<tr>
<td>Sessions</td>
<td>3924</td>
</tr>
<tr>
<td>Page views</td>
<td>11,127</td>
</tr>
<tr>
<td>Pages/session</td>
<td>2.84</td>
</tr>
<tr>
<td>Average session duration</td>
<td>1.51 minutes</td>
</tr>
<tr>
<td>New visitors, n (%)</td>
<td>3143 (91.02)</td>
</tr>
<tr>
<td>Returning visitors, n (%)</td>
<td>310 (9.86)</td>
</tr>
</tbody>
</table>

Table 2. Google Analytics data on device type used to access website and website traffic collected from dementia613.ca from January to October 2021.

<table>
<thead>
<tr>
<th>Device of access to website (n=74)</th>
<th>Values, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop</td>
<td>62 (84)</td>
</tr>
<tr>
<td>Mobile</td>
<td>11 (15)</td>
</tr>
<tr>
<td>Tablet</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Website traffic (n=3924)</td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>2402 (61.21)</td>
</tr>
<tr>
<td>Referral</td>
<td>736 (18.76)</td>
</tr>
<tr>
<td>Organic search</td>
<td>556 (14.17)</td>
</tr>
<tr>
<td>Social</td>
<td>228 (5.18)</td>
</tr>
</tbody>
</table>

Textbox 1. Google Analytics data on top website content viewed collected from dementia613.ca from January to October 2021.

<table>
<thead>
<tr>
<th>Top website content viewed</th>
</tr>
</thead>
<tbody>
<tr>
<td>/resources/</td>
</tr>
<tr>
<td>/category/fitness-exercise-learning/</td>
</tr>
<tr>
<td>/category/health-well-being-caregiver-services/</td>
</tr>
<tr>
<td>/fr/acceuil/</td>
</tr>
<tr>
<td>/category/food-beverage/</td>
</tr>
<tr>
<td>/add-resource/</td>
</tr>
<tr>
<td>/category/safety-monitoring/</td>
</tr>
<tr>
<td>/category/housing-transportation/</td>
</tr>
</tbody>
</table>

Self-administered Questionnaires

Overview

For the English and French versions of the website, 64% (39/61) of the respondents completed the questionnaire (out of the respondents who started it). Of these completed responses, 96% (28/29) of the responses were to the Care Partner and Persons Living with Dementia Questionnaire in English, 3% (1/29) to the Care Partner and Persons Living With Dementia Questionnaire in French, and 10 responses to the Business and Organization Questionnaire in English.

Most Care Partner and Persons Living with Dementia respondents (26/29, 90%) identified as woman and were aged >65 years (15/29, 52%). The majority of respondents (19/29, 66%) identified their role as being a care partner to an individual living with memory difficulties or dementia. Most Business and Organization respondents (6/10, 60%) worked for a health care organization.

Most Care Partners and Persons Living With Dementia respondents had been to dementia613.ca >5 times. The largest segment of Business and Organization respondents had used dementia613.ca between 2 and 4 times. Table 3 presents the results of the dementia613.ca questionnaires.
Table 3. Descriptive characteristics and frequency distribution for users of dementia613.ca, care partners and person living with dementia, and businesses and organizations.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Care partner and person living with dementia questionnaire (N=29), n (%)</th>
<th>Business and organization questionnaire (N=10, n (%))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td>3 (10)</td>
<td>N/Aa</td>
</tr>
<tr>
<td>Woman</td>
<td>26 (90)</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-35</td>
<td>3 (10)</td>
<td>N/A</td>
</tr>
<tr>
<td>36-45</td>
<td>3 (10)</td>
<td>N/A</td>
</tr>
<tr>
<td>46-55</td>
<td>0 (0)</td>
<td>N/A</td>
</tr>
<tr>
<td>56-64</td>
<td>8 (28)</td>
<td>N/A</td>
</tr>
<tr>
<td>&gt;65</td>
<td>15 (52)</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual living with memory difficulties or dementia</td>
<td>0 (0)</td>
<td>N/A</td>
</tr>
<tr>
<td>Care partner to an individual with memory difficulties or dementia</td>
<td>19 (66)</td>
<td>N/A</td>
</tr>
<tr>
<td>Individual who works with people living with dementia</td>
<td>5 (17)</td>
<td>N/A</td>
</tr>
<tr>
<td>Health care professional</td>
<td>3 (10.3)</td>
<td>N/A</td>
</tr>
<tr>
<td>DSORCb volunteer</td>
<td>2 (7)</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Organization type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government</td>
<td>N/A</td>
<td>1 (10)</td>
</tr>
<tr>
<td>Health care</td>
<td>N/A</td>
<td>6 (60)</td>
</tr>
<tr>
<td>Other</td>
<td>N/A</td>
<td>3 (30)</td>
</tr>
<tr>
<td><strong>Approximate number of employees</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20</td>
<td>N/A</td>
<td>4 (40)</td>
</tr>
<tr>
<td>Between 20 and 99</td>
<td>N/A</td>
<td>3 (30)</td>
</tr>
<tr>
<td>Between 100 and 499</td>
<td>N/A</td>
<td>1 (10)</td>
</tr>
<tr>
<td>&gt;500</td>
<td>N/A</td>
<td>2 (20)</td>
</tr>
<tr>
<td><strong>Frequency of use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Once</td>
<td>2 (7)</td>
<td>1 (10)</td>
</tr>
<tr>
<td>&lt;5 times</td>
<td>8 (28)</td>
<td>4 (40)</td>
</tr>
<tr>
<td>Between 5 and 9 times</td>
<td>10 (34)</td>
<td>3 (30)</td>
</tr>
<tr>
<td>&gt;10 times</td>
<td>9 (31)</td>
<td>2 (20)</td>
</tr>
</tbody>
</table>

aN/A: not applicable
bDSORC: Dementia Society of Ottawa and Renfrew County

**Content and Ease of Use**

More than 70% (21/29, 72%) of the care partners and Persons Living respondents and 100% (10/10) of Businesses and Organization respondents strongly agreed or agreed that the website contained relevant information. Figure 1 presents the respondents’ ratings of the design, content, and ease of use of dementia613.ca.
Usefulness of Features

Most of the questionnaire respondents found features of dementia613.ca helpful (Figure 2). Approximately 70% (20/29, 69%) of Care Partners and Persons Living With Dementia respondents strongly agreed or agreed that the way the resources were organized in categories was helpful, and 90% (9/10) of Businesses and Organizations respondents strongly agreed or agreed that the information provided on becoming dementia friendly was helpful.

However, some features of dementia613.ca were not viewed favorably. Only 48% (14/29) of Care Partners and Persons Living With Dementia respondents strongly agreed or agreed that it was helpful to search for resources using the map view.
Figure 2. Users’ ratings of specific features of the website dementia613.ca, care partners and persons living with dementia (N=29), and businesses and organizations (N=10).

User Satisfaction With Website

As shown in Figure 3, the overall user satisfaction with dementia613.ca was very high. More than 90% (27/29, 93%) of Care Partners and Persons Living With Dementia respondents and 100% (10/10) of Businesses and Organizations respondents were very satisfied or somewhat satisfied with the website. In addition, users came away with an overall positive impression of dementia613.ca. More than 80% (24/29, 83%) of Care Partners and Persons Living With Dementia respondents and 100% (10/10) of Businesses and Organizations respondents plan to visit dementia613.ca again (Figure 4).
Figure 3. Overall satisfaction with the website dementia613.ca, care partners and person living with dementia (N=29), and businesses and organizations (N=10).
Open-ended Responses

The respondents were asked to answer specific questions at the end of the questionnaire. Descriptive coding, a type of first-cycle qualitative coding, was used to analyze the comments. In “descriptive coding,” codes are used to summarize the main topic of a passage of qualitative data [27]. This method allows responses to be grouped by theme. All the comments can be found in Multimedia Appendix 4.

Most comments were positive, stating that the website was a good resource for finding local resources, and that there was no equivalent local resource. Examples of the positive comments for each identified theme are listed in Table 4.

Negative comments were helpful because they often either critiqued specific features or offered advice on how to improve websites. Several comments noted that the lack of a search function made it challenging to find specific resources. Other comments noted that although the categories used to organize resources were helpful, the resources in each category appeared disorganized. Representative negative comments for each theme are presented in Table 5.
<table>
<thead>
<tr>
<th>Question and theme</th>
<th>Questionnaire type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you only used the website once, why did you NOT return?</td>
<td>Newly launched resource</td>
<td>Business and organization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Care partner and person living with dementia</td>
</tr>
<tr>
<td></td>
<td>What is the reason or reason(s) you are using the website?</td>
<td>Supporting friends and family</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supporting clients</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supporting care partners</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supporting business development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education on dementia</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Convince</td>
</tr>
<tr>
<td></td>
<td>Do you have any other thoughts you would like to share about the website?</td>
<td>Website is helpful</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Open-ended comments from respondents—negatives and suggestions for improvement.

<table>
<thead>
<tr>
<th>Question and theme</th>
<th>Questionnaire type</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you only used the website once, why did you NOT return?</td>
<td>Hard to navigate • Care partner and person living with dementia</td>
<td>“No alphabetical index. No search engine. Topic categories too broad.”</td>
</tr>
<tr>
<td></td>
<td>Location • Care partner and person living with dementia</td>
<td>“Because I found it was more suited if you lived in Ottawa.”</td>
</tr>
<tr>
<td></td>
<td>Location • Care partner and person living with dementia</td>
<td>“I need a list of Memory Care facilities in [my neighborhood] but your website has none listed.”</td>
</tr>
<tr>
<td>Are there any other features you would like us to add?</td>
<td>Navigation features • Care partner and person living with dementia</td>
<td>“Search engine and index.”</td>
</tr>
<tr>
<td></td>
<td>Listing order • Care partner and person living with dementia</td>
<td>“List things alphabetically in categories. It’s very scattered.”</td>
</tr>
<tr>
<td></td>
<td>Listing order • Business and organization</td>
<td>“Alphabetical order would be helpful—or maybe list the agencies that are dementia friendly first, then the others? There seems to be absolutely no logical order.”</td>
</tr>
<tr>
<td></td>
<td>Categories • Care partner and person living with dementia</td>
<td>“Make the categories less broad—under Food &amp; Beverage, I found 211 Ontario.”</td>
</tr>
<tr>
<td></td>
<td>Cost information • Care partner and person living with dementia</td>
<td>“Separate out listings by region.”</td>
</tr>
<tr>
<td></td>
<td>Do you have any other thoughts you would like to share about the website?</td>
<td>“If there is a cost involved for example; fitness the cost should be stipulated.”</td>
</tr>
<tr>
<td>Hard to navigate • Care partner and person living with dementia</td>
<td>“Search filter feature per category seems unreliable...hard to navigate to find what you’re looking for.”</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Business and organization</td>
<td>“The search features are not working properly.”</td>
</tr>
</tbody>
</table>

Task Analysis

We conducted 5 task analysis sessions. Three participants had been care partners for a family member with dementia. Two participants had mild cognitive impairments. Furthermore, 2 of the participants were in Ottawa and the other 3 were in rural communities. Two participants self-identified as older adults (aged ≥65 years). Further details can be found in Table 6.

During the task analysis sessions, the participants were given a scenario and asked to complete 4 related tasks. The amount of time it took for users to finish the tasks was recorded, and the average successful completion time for each task is presented in Table 7. The reasons for unsuccessful task completion were as follows: in task 1 a participant did not know what category to select and gave up on the task; in task 2, a participant selected individual listings one-by-one and looked at their addresses on the full resource listing page; in task 4, a total of 2 users selected Contact Us instead of the correct choice About.

The data collected during the task analysis sessions were synthesized into takeaways based on 7 categories from User Experience Honeycomb of Morville [20,21]. Overall, most of the feedback participants provided during these sessions was positive. Fundamentally, participants found the idea behind dementia613.ca to be good and they found the information provided to be helpful. Participants thought that the information was reliable, in large part, because of the positive reputation of the DSORC. The participants also found dementia613.ca to be accessible. The positive takeaways are listed in Table 8. However, participants also identified several areas in which dementia613.ca could be improved. The area that needs the most improvement is the overall website navigation. Users found that the organization of the website content could be improved and that specific listings were difficult to find. In addition, some users would have liked to see that business and organization listings contained more specific information. Negative and neutral takeaways are presented in Table 9.
Table 6. Demographic information on task analysis participants.

<table>
<thead>
<tr>
<th>Code</th>
<th>Previously used dementia613.ca</th>
<th>Device</th>
<th>Location</th>
<th>Age (years)</th>
<th>Relation to research</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Yes</td>
<td>Desktop</td>
<td>Ottawa, Ontario</td>
<td>&lt;65</td>
<td>Care partner</td>
</tr>
<tr>
<td>P2</td>
<td>Yes</td>
<td>Tablet</td>
<td>Renfrew, Ontario</td>
<td>≥65</td>
<td>Care partner</td>
</tr>
<tr>
<td>P3</td>
<td>No</td>
<td>Tablet</td>
<td>Ottawa, Ontario</td>
<td>≥65</td>
<td>Mild cognitive impairment</td>
</tr>
<tr>
<td>P4</td>
<td>No</td>
<td>Desktop</td>
<td>South Hampton, Ontario</td>
<td>&lt;65</td>
<td>Mild cognitive impairment</td>
</tr>
<tr>
<td>P5</td>
<td>No</td>
<td>Desktop</td>
<td>South Hampton, Ontario</td>
<td>&lt;65</td>
<td>Care partner</td>
</tr>
</tbody>
</table>

Table 7. Success rate and average completion time for tasks given to participants during task analysis sessions (n=5).

<table>
<thead>
<tr>
<th>Task</th>
<th>Question asked</th>
<th>Success rate, n (%)</th>
<th>Average time for successful completion (min:sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1: finding information about courses or programs related to arts and crafts</td>
<td>Where would you expect to find information about courses or programs related to arts and crafts?</td>
<td>4 (80)</td>
<td>1:31</td>
</tr>
<tr>
<td>Task 2: finding which listings are close to your location</td>
<td>How would you go about finding which listings are close to your location?</td>
<td>4 (80)</td>
<td>1:27</td>
</tr>
<tr>
<td>Task 3: finding detailed information about a resource</td>
<td>Once you have found a resource that interests you, how might you find out more detailed information about it?</td>
<td>5 (100)</td>
<td>0:24</td>
</tr>
<tr>
<td>Task 4: finding information about the organizations(s) that run dementia613.ca</td>
<td>Where would you expect to find information about the organizations(s) that run this website?</td>
<td>3 (60)</td>
<td>1:11</td>
</tr>
</tbody>
</table>

Table 8. Takeaways from task analysis session data synthesized using categories from Peter Morville’s User Experience Honeycomb—positive.

<table>
<thead>
<tr>
<th>Category and key takeaways</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Useful</strong></td>
<td></td>
</tr>
<tr>
<td>The resources provided are relevant to user needs.</td>
<td>“These listings look like places I would go.”</td>
</tr>
<tr>
<td>The full listing pages of resources provide important and relevant information.</td>
<td>“This page provides a good overview of information (contact, blurb, etc.).”</td>
</tr>
<tr>
<td><strong>Valuable</strong></td>
<td></td>
</tr>
<tr>
<td>Provides enough information for a user to know if a resource is relevant.</td>
<td>“Gives the information you need to make a decision.”</td>
</tr>
<tr>
<td>Provides users with multiple ways to connect organizations to find more information.</td>
<td>“Gives enough information to know if organization is of interest and to contact them to learn more.”</td>
</tr>
<tr>
<td><strong>Credible</strong></td>
<td></td>
</tr>
<tr>
<td>Strong positive reputation of DSORC.</td>
<td>“I assume that I can trust it because it was put there by The Dementia Society.”</td>
</tr>
<tr>
<td>Can directly contact organizations from listings.</td>
<td>“I see this information as reliable. I like that there are multiple methods to contact the organization.”</td>
</tr>
<tr>
<td><strong>Accessible</strong></td>
<td></td>
</tr>
<tr>
<td>Content is legible.</td>
<td>“Content is easy to see; bold items, font size, it’s easy to read, and gives the right information.”</td>
</tr>
<tr>
<td>Content is easy to understand.</td>
<td>“Wording was good, and language was understandable.”</td>
</tr>
<tr>
<td><strong>Desirable</strong></td>
<td></td>
</tr>
<tr>
<td>Concept behind dementia613.ca initiative is good.</td>
<td>“Overall, this could be a good resource.”</td>
</tr>
<tr>
<td><strong>Findable</strong></td>
<td></td>
</tr>
<tr>
<td>Information on resource listings is well organized.</td>
<td>“The listing is good and makes finding things easier.”</td>
</tr>
</tbody>
</table>

*DSORC: Dementia Society of Ottawa and Renfrew County.*
Table 9. Takeaways from task analysis session data synthesized using categories from Peter Morville’s User Experience Honeycomb—negative or neutral.

<table>
<thead>
<tr>
<th>Category</th>
<th>Key takeaways</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useful</td>
<td>The full listing pages of resources does not provide enough information.</td>
<td>“I would want more detailed and specific information about this resource.”</td>
</tr>
<tr>
<td>Valuable</td>
<td>Some resource descriptions are not specific enough.</td>
<td>“Some of the descriptions for the resources are not helpful. They should say exactly what the resources are.”</td>
</tr>
<tr>
<td>Usable</td>
<td>Overall navigation needs improvement.</td>
<td>“Navigation should be made easier, without so much clicking.”</td>
</tr>
<tr>
<td>Accessible</td>
<td>Content legibility could be improved.</td>
<td>“Font size needs work in places.”</td>
</tr>
<tr>
<td>Findable</td>
<td>Content is poorly organized.</td>
<td>“Content is useful, but could be organized better.”</td>
</tr>
</tbody>
</table>

**Discussion**

**Principal Findings**

Our evaluation showed that the idea behind dementia613.ca is strong and appeals to persons living with dementia and the stakeholders who serve them. Our evaluation found that although most users were new to the site, they were interested in using it again. Users saw the information on dementia613.ca as credible and felt that it provided them with relevant resources and information. Overall, the website reflects the basic ingredients needed to support a good user experience, aligning with Morville’s principles of “valuable” and “useful” [20,21].

The evaluation also identified some areas where dementia613.ca could be improved, namely navigation and search, and clarity around the website’s purpose. The needed changes will align the website with the principles of “findable” and “usable” by Morville [20,21]. We are hopeful that with these refinements, and as dementia613.ca becomes a more established and well-known resource, the site will better serve new and existing users.

**Relevance to Community**

Participants shared that dementia613.ca is a useful community resource. The development process we went through to create the website involved consulting relevant members of the community (persons living with dementia, care partners, businesses, and organizations). The website was shaped by an image of their needs and desires. Our success can be seen by users citing reasons that aligned with the motivation behind its creation, such as supporting the community and providing convenient resources when asked why they were using the website. Furthermore, in task analysis sessions, several participants indicated that they saw the website as desirable, as exemplified by the comment “Overall, this could be a good resource.” This shows dementia613.ca’s alignment with the principle of “valuable” by Morville [20,21] by demonstrating that the website provides users with important information. Dementia613.ca is a useful resource that meets previously unmet local needs.

More specifically, dementia613.ca provided relevant resources and information to persons living with dementia and their care partners and to businesses and organizations that want to be dementia-inclusive. When asked, >60% (19/29, 66%) of persons living with dementia and their care partners and 70% (7/10) of businesses and organizations agreed that the website made it easier to find relevant dementia-inclusive resources. In open-ended responses, one participant said, “It has been very helpful for me. I have learned how to cope better. THANK YOU!” This shows dementia613.ca’s alignment with Morville’s principle of “useful” [20,21], demonstrating that the website serves a purpose for our stakeholders. All of this illustrates that dementia613.ca is meeting local needs by providing relevant resources and information.

Dementia613.ca is aimed at care partners, who can be of a wide variety of ages, and persons with mild cognitive impairment. It was designed to meet the needs of these users; however, we recognize that it may also be used by people outside of those demographics. To ensure that the site would be as wide as possible, we were guided by Peter Morville’s User Experience Honeycomb framework [20,21] and usability design best practices promoted by the Nielsen-Norman Group [22,23]. We also referred to Web Content Accessibility Guidelines 2.1 [26] to develop the site. Because of the principles we followed during its creation, we feel that dementia613.ca supports accessibility and the inclusion of a variety of stakeholders, recognizing that there is always room for improvement as we learn about the site in use over time.

**Areas for Improvement and Future Research**

Participants provided constructive feedback that was used to produce further iterations of the design. Areas for improvement include the following:

- Refining how a website is organized as many users found it challenging to navigate. The most suggested improvement was organizing the service listings in an alphabetical order. Another suggestion is to narrow or further specify the categories provided or allow users to filter results within a category. The literature in this area aligns with these recommendations, finding that users appreciate well-designed tools to narrow search results [28]. In the next round of design and development for dementia613.ca, we will work with stakeholders to develop a more usable navigation structure. This will increase the website’s alignment with Morville’s principles of “findable” and “usable” [20,21] by improving website navigation and making it easier for users to find information they seek.

- Adding a search feature, as many users noted that the map view was not sufficient for finding specific resources. Research in this area has found that website users are goal-driven and look only for the one thing they have in

https://aging.jmir.org/2023/1/e40762 JMIR Aging 2023 | vol. 6 | e40762 | p.222 (page number not for citation purposes)
mind and often rely on searching in pursuit of their goal [29]. This supports the findings of our task analysis and strengthens the case of adding a search feature. There are established best practices for developing strong on-site search engines that enable good user experience [30]. However, best practices also caution against prioritizing searches at the expense of navigation [31]. Thus, in the next round of design and development for dementia613.ca, we will work to develop both search and navigation and ensure alignment between these tools. This will further increase the website’s alignment with the principles of “findable” and “usable” [20,21].

- It is more explicit about who the website is for and what information it provides. Some users seemed unclear about the purpose of the website. In addition, a surprisingly high number of users from outside Ottawa have accessed this website. We are not sure why this occurred but it could be due to the site appearing in people’s search queries, word of mouth from people receiving the recruitment notice and passing the information onto community members outside the region, or other potential factors. This may mean that we need to clarify the purpose of the website and make it more obvious that the resources are for Ottawa and the surrounding areas.

The Google Analytics data we collected indicate that users, on average, did not spend a long time on individual pages of dementia613.ca. This could mean that individuals were looking for a specific resource or answering a specific question and were able to find the page they needed quickly. This interpretation aligns with the results from our questionnaire: approximately 60% (17/29, 59%) of the care partners and Persons Living With Dementia respondents strongly agreed or agreed that they were quickly able to find the information they were interested in on the website. However, short site visits could also indicate that individuals visiting the site only quickly browsed the resources before leaving, perhaps not finding useful information. Further studies are needed to understand this phenomenon. In addition, only 9% (310/3453, 8.98%) of the website visitors returned. This may be due to the timing of Google Analytics data collection, which was shortly after the launch of the website. This did not give the site much time to build a user base. Taken together, Google Analytics data brings up good points for future work to evaluate the website, which should aim to include a sample of previous website users. It should ask questions about their perceptions of the site’s utility, their primary uses for the site (using the website to find one specific resource vs using it to search for multiple different types of resources available in the area), and their reasons for returning to the site.

**Relevance to the Development of eHealth Resources**

Not all web-based health resources are created equally, and the best attempts at providing useful information can fall short. To address this, there is a growing body of research on the specific information needs of internet users and their requirements for web-based health information [32]. There is also more specialized research on the barriers faced by users from marginalized populations [33,34]. A common thread among these studies is the importance of incorporating user feedback, priorities, and concerns into the design of web-based health resources. This information can be gathered by conducting evaluations with users, making it a critical step in creating useful web-based health resources.

Currently, there is a limited amount of literature evaluating public-facing health resource websites. Much of the existing research focuses on e-mental health resources [18,35-38]. These studies have found that the general public is interested in accessing quality-health resources on the web [35,39]. This aligns with our results and demonstrates the need for an increased number of reliable, public-facing health resource websites.

Other studies have found that there is a specific interest in accessing quality health resources on the web among traditionally underserved populations, including people in rural communities [40], persons with mild-intellectual disability [38,41], and adolescents and their parents [33,42]. Currently, there are scant quality web-based health resources for care partners of persons living with dementia; however, they are an overworked and overwhelmed group [7,8] that would greatly benefit from the support that this type of resource can provide. Persons living with dementia are a similarly underserved population. Dementia613.ca aims to serve both types of demographics.

Within the context of design, there is growing literature on best practices for evaluating websites in the health sector. Currently, work in this area often focuses on the websites of health institutions, such as hospitals and health departments [43-46]. This literature emphasizes the importance of working with communities and using a mixed methods approach to ensure that feedback is well-rounded and relevant [43,45]. Although dementia613.ca is a website for community resources, not for a health institution, we feel that the broader principles advanced in this body of research are aligned with these principles and approaches.

**Limitations**

This study has several limitations. First, web analytics were only collected for 9 months, which is a shorter time frame than has been used in comparable research projects where the analytics have captured 12 months of data [18]. Furthermore, during the initial weeks in which web analytics were collected, final changes were made to the website design. In addition, during the data collection period, dementia613.ca was a newly launched website without an established user base. Thus, there is limited traffic to capture in the web analytics data. In future research, analytics should be conducted over a longer period. In addition, in any future evaluation, dementia613.ca will be more established, presumably with a larger flow of traffic.

The number of responses to the web-based questionnaires was small, leading to a limited sample size, especially for the Businesses and Organizations group. There were only 10 responses from this group, representing the health care and government sectors. This limited sample size could be viewed as homogenous. Future studies could benefit from purposive sampling to engage broader sector representation (ie, government organizations, community organizations, and private
industry) to determine how well the site serves different needs and expectations among service providers.

The Care Partners and Persons Living With Dementia respondents skewed toward older adults and woman. Dementia613.ca was not specifically created for this demographic, suggesting that its responses may not be representative of all website users. Further research should gather feedback from a broader range of users; however, the testing done during phases 1 and 2 had responses from participants with a wide range of ages. Approximately 70% (34/46, 74%) of the responses to the phase 1 questionnaire were from individuals aged <65 years. Similarly, in phase 2, all 5 participants in the task analysis sessions were between the ages of 40 and 65 years. Thus, the site was developed using feedback from different age groups.

Furthermore, no one who self-identifies as an “individual living with memory difficulties or dementia” completed the web-based questionnaire. We promoted the study to this population through posters displayed at a Geriatric Day Hospital and Memory Clinic and in the Dementia Society Monthly Newsletter, but unfortunately did not receive any responses from this population. This limits the usability of the questionnaire results for understanding the population. However, 2 of the 5 participants in the task analysis sessions had mild cognitive impairment. Thus, the data from the task analysis sessions indicate that the initial design of dementia613.ca is appropriate for this stakeholder group. This information will be helpful to DSORC staff member when planning the future promotion of the website to both care partners and persons living with dementia.

Although Neilsen [22,23] suggested that 5 users are a reasonable number to conduct an evaluation of a website, a limited number of task analysis sessions were conducted. It has also been suggested that for qualitative studies using nonprobability sampling techniques with a homogeneous population, saturation (where potentially similar patterns emerge and no new information or insight emerges) can occur with 4-12 participants [47,48]. The small number of participants could mean that the results of the task analysis were not representative of all website users. This could be addressed in future research by reaching out to more potential participants (eg, from each stakeholder group of persons living with dementia, care partners, and businesses or organizations) and having a longer testing period. Despite this, we believe that there were enough participants to achieve saturation for the initial design of dementia613.ca.

Taken together, the amount of data collected through web analytics, questionnaires, and task analysis sessions provided enough information for an initial evaluation of the utility and ease of use of the website. The data will be used as the basis for future work aimed at improving dementia613.ca.

Conclusions

Dementia613.ca was well received by most of the visitors. It will be a useful resource for the Ottawa area; according to the feedback we were able to collect from business owners and care partners. The participants indicated that they met a previously unfiled need in the area. Participants highlighted the utility of bringing local resources together in a web-based format in dementia613.ca. Both persons living with dementia and their care partners and businesses and organizations said that dementia613.ca provided reliable and relevant information. There is still room for improvement; participants pointed out that navigation and search features could be developed further. With further updates to the website, methods similar to those outlined in this paper will be used to obtain additional user feedback for further evaluation.

This website model can be used to inspire and guide the creation of dementia resource websites in other regions in Ontario and Canada. We believe that the framework behind dementia613.ca is generalizable and could be replicated in other regions to help care partners and persons living with dementia find local resources more easily.

Acknowledgments

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Conflicts of Interest

DH is an employee of the Dementia Society of Ottawa and Renfrew County. Authors MT, CT, and NT have no conflicts of interest to declare.

Multimedia Appendix 1

Phase 1 survey: questions and responses.
[XLSX File (Microsoft Excel File), 19 KB - aging_v6i1e40762_app1.xlsx]

Multimedia Appendix 2

Complete the questionnaire in English. Care partners and persons living with dementia filled out questions 1-14, and businesses and organizations filled out questions 1 and 15-26.
[DOCX File , 80 KB - aging_v6i1e40762_app2.docx]


40. Schoenengraf N, Dunfee M, Yeager H, Rutledge M, Pfammatter A, Spring B. Rural residents’ perspectives on an mHealth or personalized health coaching intervention: a qualitative study with focus groups and key informant interviews. JMIR Form Res 2021 Feb 26;5(2):e18853 [FREE Full text] [doi: 10.2196/18853] [Medline: 33655278]


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Abbreviations

DSORC: Dementia Society of Ottawa and Renfrew County

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Development and Initial Evaluation of Web-Based Cognitive Behavioral Therapy for Insomnia in Rural Family Caregivers of People With Dementia (NiteCAPP): Mixed Methods Study

Christina S McCrae1,2, PhD; Ashley F Curtis2, PhD; Melanie A Stearns2, PhD; Neetu Nair1, PhD; Mojgan Golzy3, PhD; Joel I Shenker4, MD, PhD; David Q Beversdorf4,5,6,7, MD; Amelia Cottle, BA; Meredith A Rowe2, PhD

1Department of Psychiatry, University of Missouri, Columbia, MO, United States
2College of Nursing, University of South Florida, Tampa, FL, United States
3Department of Family and Community Medicine, University of Missouri, Columbia, MO, United States
4Department of Neurology, University of Missouri, Columbia, MO, United States
5Departments of Radiology, University of Missouri, Columbia, MO, United States
6Department of Psychological Sciences, University of Missouri, Columbia, MO, United States
7The Thompson Center for Autism and Neurodevelopmental Disorders, University of Missouri, Columbia, MO, United States

Corresponding Author:
Christina S McCrae, PhD
College of Nursing
University of South Florida
12912 USF Health Dr
Tampa, FL, 33612
United States
Phone: 1 813 974 1804
Email: christinamccrae@usf.edu

Abstract

Background: Informal caregivers of people with dementia frequently experience chronic insomnia, contributing to stress and poor health outcomes. Rural caregivers are particularly vulnerable but have limited access to cognitive behavioral therapy for insomnia (CBT-I), a recommended frontline treatment for chronic insomnia. Web-based delivery promises to improve insomnia, particularly for rural caregivers who have limited access to traditional in-person treatments. Our team translated an efficacious 4-session standard CBT-I content protocol into digital format to create NiteCAPP.

Objective: This study aimed to (1) adapt NiteCAPP for dementia caregivers to create NiteCAPP CARES, a tailored digital format with standard CBT-I content plus caregiver-focused modifications; (2) conduct usability testing and evaluate acceptability of NiteCAPP CARES’ content and features; and (3) pilot-test the adapted intervention to evaluate feasibility and preliminary effects on sleep and related health outcomes.

Methods: We followed Medical Research Council recommendations for evaluating complex medical interventions to explore user needs and adapt and validate content using a stepwise approach: (1) a rural dementia caregiver (n=5) and primary care provider (n=5) advisory panel gave feedback that was used to adapt NiteCAPP; (2) caregiver (n=5) and primary care provider (n=7) focus groups reviewed the newly adapted NiteCAPP CARES and provided feedback that guided further adaptations; and (3) NiteCAPP CARES was pilot-tested in caregivers (n=5) for feasibility and to establish preliminary effects. Self-report usability measures were collected following intervention. Before and after treatment, 14 daily electronic sleep diaries and questionnaires were collected to evaluate arousal, health, mood, burden, subjective cognition, and interpersonal processes.

Results: The stepped approach provided user and expert feedback on satisfaction, usefulness, and content, resulting in a new digital CBT-I tailored for rural dementia caregivers: NiteCAPP CARES. The advisory panel recommended streamlining content, eliminating jargon, and including caregiver-focused content. Focus groups gave NiteCAPP CARES high usefulness ratings (mean score 4.4, SD 0.79, scored from 1=least to 5=most favorable; score range 4.2-4.8). Multiple features were evaluated positively, including the intervention’s comprehensive and engaging information, caregiver focus, good layout, easy-to-access intervention material, and easy-to-understand sleep graphs. Suggestions for improvement included the provision of day and night viewing options, collapsible text, font size options, tabbed access to videos, and a glossary of terms. Pilot-test users rated usefulness (mean score 4.3, SD 0.83; range 4.1-4.5) and satisfaction (mean score 8.4, SD 1.41, scored from 1=least to 10=most satisfied; range...
Overview

Approximately 16 million Americans serve as informal caregivers, providing 18.5 billion hours of care, which translates into US $234 billion in health care savings [1]. Dementia caregiving in particular is more demanding than other types of caregiving, due in part to time-consuming and unpredictable caregiving demands and associated emotional and physical exhaustion [1,2]. Informal caregivers of people with dementia frequently experience insomnia [3,4]. The number of people with dementia in the United States is projected to rise from 5.7 million to more than 14 million in the next 30 years [5]. Most people with dementia (70%) are cared for at home by a family member [1]. Thus, there is a critical need to evaluate the health of dementia caregivers and provide treatment for prevalent medical conditions such as insomnia.

In addition, because rural areas are aging faster than urban areas, the proportion of people at risk for dementia is growing faster, which translates to faster growth in the proportion of rural caregivers [6]. Compared to their urban counterparts, rural caregivers face additional challenges, including more difficulty accessing health care, a greater likelihood of social isolation, and increased vulnerability to sleep problems, stress, and depression. Rural caregivers have less access to care due to significant shortages of both primary and specialty care providers in rural areas [7,8] and are also at disproportionate risk for poverty and unemployment [2], which further limits their access. On average, they travel 144 km roundtrip to see their nearest health care provider [9]. Lengthy travel combined with the lack of public transportation in rural areas represent an additional major barrier to access. Thus, developing and evaluating treatments for medical conditions that are prevalent in caregivers (eg, insomnia) that can be accessed remotely (eg, on the internet) is a critical and currently unmet need in the health care community.

Research from our group and others verifies that caregivers, rural caregivers face particular difficulties accessing behavioral treatments, which require specially trained providers and administration over multiple sessions in a provider’s office. In a recent randomized controlled trial, our group found that brief CBT-I delivered through telehealth (videoconferencing) reduced caregiver sleep onset latency compared to sleep hygiene education in caregivers. Our CBT-I protocol was adapted with permission from McCurry and colleagues’ [3] earlier version [21] and included standard CBT-I techniques (sleep hygiene, stimulus control, and cognitive therapy), modified CBT-I techniques (sleep compression replaces sleep restriction, which is potentially burdensome for caregivers due to temporary sleep deprivation; brief hybrid relaxation is included given caregiver time constraints [22]; and muscle tensing is excluded given potential pain or musculoskeletal issues in older caregivers), additional techniques for caregivers (problem-solving, as skill deficiency can contribute to caregiver insomnia [23,24]), and stress management (respite, staying healthy, and communication). Our findings indicate CBT-I tailored for caregivers translates well to telehealth delivery and that technology holds great potential to increase rural caregiver access to behavioral interventions. However, telehealth delivery still requires considerable time commitment from trained therapists (who are already in short supply).

A small but growing body of evidence shows that web interventions have been successfully implemented in rural areas using the internet and other mobile platforms and improved noninsomnia health outcomes in stroke and caregivers [25-32]. Moreover, web-based CBT-I has been implemented and found to be efficacious in noncaregiver patient populations. For example, Taylor et al [33] translated 6-week CBT-I to a web format and conducted a randomized controlled trial in military personnel (N=100; n=33 received web CBT-I, n=34 received in-person CBT-I, and n=33 received minimal contact control).

7.4-9.0) highly. Preliminary effects on caregiver sleep, arousal, health, mood, burden, cognition, and interpersonal processes (all \( P < .05 \)) were promising.

Conclusions: Adaptations made to standard digital CBT-I created a feasible, tailored digital intervention for rural dementia caregivers. Important next steps include further examination of feasibility and efficacy in a randomized controlled trial with an active control condition, a multisite effectiveness trial, and eventual broad dissemination.

Trial Registration: ClinicalTrials.gov NCT04632628; https://clinicaltrials.gov/ct2/show/NCT04632628

(JMIR Aging 2023;6:e45859) doi:10.2196/45859

KEYWORDS
arousal; caregivers; cognitive behavioral therapy; CBT: cognitive behavioral therapy for insomnia; CBT-I; dementia; insomnia; internet

Introduction
Compared to control, web-based and in-person CBT-I improved sleep efficiency, sleep onset latency, and wake time after sleep onset (effects moderate for web-based, large for in-person). Internet CBT-I also improved insomnia severity and decreased sleep-related cognitive arousal [33]. Another 6-week web-based CBT-I program (SHUTi) [34] was shown to improve insomnia severity (as measured through the insomnia severity index) relative to a no-contact control (large effect size) in adults with insomnia. Noted limitations of internet-based treatments include a lack of personal contact to address treatment questions or concerns without a face-to-face or telephone component. Additionally, personal support or guided delivery has been associated with larger treatment effects for both in-person and web-based CBT-I [26]. Taken together, these findings provide support for the development of web-based CBT-I for caregivers and suggest personal support or guided delivery is important to maximize treatment adherence and efficacy. Thus, our team developed a web-based CBT-I for caregivers through an iterative process.

Iterative Development Process

Following the Medical Research Council recommendations [35] for the evaluation of complex medical interventions, we conducted several steps in the initial development, pilot-testing, and evaluation of NiteCAPP CARES [36] (see Figure 1).

This paper describes stages 1a and 1b, which were conducted from 2019 to 2020. The goal of stage 1a was to translate (through feedback from caregivers and primary care providers; PCPs) an efficacious 4-session CBT-I into a web-based “NiteCAPP CARES,” a web-based behavioral treatment for insomnia for dementia caregivers that incorporates guided delivery through weekly therapist moderator feedback. A second goal of stage 1a was to conduct NiteCAPP CARES usability testing to evaluate the acceptability of its content and features. The goal of stage 1b was to pilot-test NiteCAPP CARES on several key outcomes (feasibility, favorability, satisfaction, sleep, arousal, mood, burden, and cognition) in a small sample of dementia caregivers. We hypothesized that NiteCAPP CARES would produce high ratings regarding favorability of program content. Further, we hypothesized that in the pilot study, participants would complete all 4 sessions on average and that satisfaction ratings would be at least more than 7 of 10 (highest) and usefulness ratings would be at least more than 4 of 5 (highest). Although the single-arm design of this pilot study precludes examination of efficacy, within-group effects of the treatment on sleep and related behaviors were also examined. We hypothesized that subjective sleep would improve immediately following treatment using NiteCAPP CARES. We further hypothesized that daytime functioning (ie, mood, caregiving burden, perceived stress, and cognition) would improve.

Methods

Stage 1a: Explore Stakeholder Views and Focus Groups

Participants

Purposeful criterion-i sampling, a nonrandom sampling method where individuals are selected because they have expertise or experience related to the study purpose, was used for both the advisory panel and focus group [37-39].

Advisory Panel

Stage 1a usability testing and validation of NiteCAPP content was first conducted by our web-based advisory panel of dementia caregivers (n=5; 3 of which were part of our community advisory board) and dementia experts, or PCPs (n=5; 2 of which are also part of our community advisory board). Participants were recruited through University of Missouri clinics, other providers, and the participant recruiter (AC). These individuals tested the NiteCAPP website on their own computers, tablets, or phones in their homes and then completed a modified structured internet intervention usefulness questionnaire (modified from existing surveys [34,40] as well as other studies evaluating web-based behavioral interventions [27,41,42]) to provide ratings of program content (1=least favorable to 5=most favorable) regarding ease of use, amount of information, website maintaining interest, adequate font size, videos maintaining interest, easy to understand, and helpful. Participants in the advisory panel also provided open-ended verbal and written feedback.

Focus Group

Next, CSM (primary investigator) and AC (community caregiver consultant) led in-person focus groups consisting of caregivers (n=5; mean age 51.4, SD 15.9 years, age range 23-59 years; 3 female, 1 male, and 1 nonbinary; 4 White and 1 multiracial) and PCPs (n=7; mean age 45.29, SD 15.01 years; age range 26-66 years; 5 female and 2 male; 6 White and 1 multiracial). Users were provided logins and could review the NiteCAPP website (see Figure 2) on their own devices before and during the focus group.

Participants were encouraged to explore the site freely, read content, and watch and listen to audiovisual materials before
and during the focus group. CSM and AC had a list of specific questions to ask, such as the usability of the website for caregivers and how they felt about the amount of text or number of pictures and asked the questions from the internet intervention usefulness questionnaire and satisfaction questionnaire in an open-ended format. They also encouraged participants to provide open-ended verbal comments or feedback on NiteCAPP. The focus group lasted approximately 90 minutes. At the end of the focus group, participants were asked to fill out a quantitative version of the internet intervention usefulness questionnaire.

Figure 2. NiteCAPP CARES website home page.

Participants’ open-ended verbal comments were transcribed, and content analyses were performed to identify recurrent themes by CSM and AFC. Frequent topics were categorized and merged into common themes during a consensus meeting of CSM and AFC. Participants also indicated whether they had at-home internet access, indicated their method of internet access, and provided open-ended feedback on NiteCAPP.

**Stage 1b: Testing Feasibility and Preliminary Effectiveness**

**Participants**

Stage 1b development involved testing NiteCAPP CARES in a single-arm pre-post-intervention pilot study to determine feasibility. The sample included dementia caregivers who had insomnia (n=5; see Table 1). Participants were recruited through physician or investigator referral (AFC or DQB) from Columbia, Missouri, and the surrounding regions and compensated with US $40 in gift cards (US $15 at the beginning of the study and US $25 at the end of the study).

Inclusion criteria for caregivers were (1) age older than 18 years; (2) primary caregiver living with person with dementia; (3) able to read and understand English; (4) no prescribed or over-the-counter sleep medicines or stabilized for more than 6 weeks; and (5) insomnia diagnosis based on sleep complaints for more than 6 months; adequate opportunity and circumstances for sleep; and more than 1 of the following: difficulty falling asleep, staying asleep, or waking too early; daytime dysfunction (mood, cognitive, social, or occupational) due to insomnia; and Insomnia Severity Index score ≥10. Exclusion criteria for caregivers were (1) unable to consent; (2) sleep disorder other...
than insomnia (ie, sleep apnea); (3) bipolar or seizure disorder; (4) other major psychopathology except depression or anxiety (eg, suicidal ideation or intent or psychosis); (5) severe untreated psychiatric comorbidity; (6) psychotropic or other medications (eg, β-blockers) that alter sleep; and (7) nonpharmacological treatment for sleep or mood outside of the current trial.

Table 1. Pilot study caregiver participant demographics (n=5).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>62.4 (18.2)</td>
</tr>
<tr>
<td>Age range (years)</td>
<td>33-78</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>3 (60)</td>
</tr>
<tr>
<td>Relation to person with dementia, n (%)</td>
<td></td>
</tr>
<tr>
<td>Spouse</td>
<td>4 (80)</td>
</tr>
<tr>
<td>Daughter</td>
<td>1 (20)</td>
</tr>
<tr>
<td>Comorbid medical conditions, mean (SD)</td>
<td>3.2 (1.8)</td>
</tr>
</tbody>
</table>

**Procedures**

Participants were contacted through referral (AFC and DQB) and provided web-based documentation of informed consent. They were then asked to fill out a web-based screening form, including demographic information and medical history. If they qualified for the study, they filled out baseline questionnaires and electronic sleep diaries (see Measures section) and were then given access to NiteCAPP and completed the web-based 50 to 60–minute treatment sessions once per week for 4 weeks. They continued to fill out electronic daily sleep diaries throughout treatment to guide sleep prescription recommendations during treatment. Posttreatment assessment occurred immediately after treatment sessions ended and included questionnaires and daily diaries (for 2 weeks).

**Intervention**

A user-centered design approach was used and took into consideration age-related cognitive or perceptual concerns in our target population [43-47]. Interface features included (1) support for older adult readability [43,45] (eg, sans-serif typeface; font larger than 14 points; clear content headings; noncluttered backgrounds; brief videos; bright colors; visual contrast or ample white space; representative icons, such as a sleep diary icon with written diary on a bed; content enhancing, no distracting audio; clear navigation; and limited pull-down menus) and (2) ease of use (eg, simplified language, videos, pictographs, and guidance). Consistent with computer digital reminiscence and conversation aid recommendations [45], community member feedback was solicited on all aspects. Moderator feedback was provided to caregivers regarding their sleep and treatment progress. See Table 2 for session content.

**Measures**

Measures were administered at baseline and immediately after treatment, unless otherwise specified.

**Usability and Satisfaction**

The modified internet intervention usefulness questionnaire (see Methods for stage 1a) was administered at the completion of NiteCAPP CARES. A proprietary 9-item satisfaction measure was also developed and administered at the completion of NiteCAPP CARES to obtain feedback on aspects of the study, including its structure, assessments within the NiteCAPP CARES site, scheduling, working with study staff, and whether they would recommend the study to others using a 10-point Likert scale (1=strongly disagree to 10=strongly agree).

**Feasibility**

Feasibility was assessed as the number of treatment modules completed (1-4, expressed as percentage) as well as the percentage of instructions followed (assessed through treatment adherence logs completed by participants within the session modules and confirmed by therapist moderators).

**Sleep**

Daily electronic diaries were completed for 14 days at baseline and immediately after treatment on the NiteCAPP CARES website and measured sleep onset latency (lights-out until sleep onset), wake after sleep onset, and sleep efficiency (total sleep time/time in bed×100%).

The Insomnia Severity Index [48] is a 7-item measure designed to assess the nature, severity, and impact of insomnia using a 5-point Likert scale, ranging from 0 (no problem) to 4 (very
severe problem). Previous studies have shown excellent internal consistency ($\alpha = .91$), convergent validity when compared to other measures (eg, fatigue), and that a cutoff score of 10 had 86.1% sensitivity and 87.7% specificity when determining insomnia [48].

**Arousal**
The Perceived Stress Scale [49] is a 10-item measure designed to assess past-month stress levels in response to everyday situations using a 4-point Likert scale, ranging from 0 (never) to 4 (very often). It has high reliability ($\alpha > .70$) [50].

The Kingston Stress Scale [51] is a 10-item measure designed to assess 3 categories: caregiving, family, and financial issues using a 5-point Likert scale, ranging from 1 (feeling fine or no stress) to 5 (extreme stress). It has high validity ($\alpha = .82$) and reliability ($\alpha = .85$) [51].

The Dysfunctional Beliefs and Attitudes about Sleep [52] is a 30-item measure designed to assess dysfunctional beliefs and attitudes about sleep using a 10-point Likert scale, ranging from 0 (strongly disagree) to 10 (strongly agree). Previous research has shown strong reliability ($\alpha = .77$ for clinical and .79 for research samples) and temporal stability ($r = 0.83$) [52].

**Health and Mood**
The Beck Depression Inventory-II [53] is a 21-item measure designed to assess depressive symptomatology using a 4-point Likert scale, ranging from 0 (absence of symptoms) to 3 (severe). Internal consistency is 0.90, and retest reliability ranges from 0.73 to 0.96 [53].

The State-Trait Anxiety Inventory [54] is a 20-item measure designed to assess anxiety using a 4-point Likert scale, ranging from 1 (not at all) to 4 (very much so). Reliability is high, with $\alpha = .93$ for clinical and $\alpha = .92$ for nonclinical samples [55].

**Burden**
The Zarit Burden Scale [56] is a 22-item measure designed to assess burden using a 5-point Likert scale, ranging from 0 (never) to 4 (nearly always). This measure has high reliability ($\alpha = .93$) and convergent validity ($r = 0.53-0.73$) [57].

The Dementia Patient’s Caregiver-Quality of Life [58] is a 20-item measure designed to assess how caregiver quality of life changes after beginning caregiving using yes-or-no questions and a 10-point sliding scale ranging from 0 (easy) to 10 (hard).

### Cognition
Subjective cognition was measured using the Cognitive Failures Questionnaire [59], a 25-item measure designed to assess an individual’s perception of their own daily cognitive failures (eg, memory failures and distractibility) using a 5-point Likert scale, ranging from 0 (never) to 4 (very often). Higher scores indicate worse overall subjective cognition. Reliability is excellent, with $\alpha = .90$ [60].

### Qualitative Data
Participants were asked to provide qualitative feedback regarding how they felt about the written materials, audiovisual materials, and any comments or suggestions they felt would help to improve NiteCAPP CARES. Therapist moderator feedback was also solicited regarding suggestions to refine and improve the guided web-based support.

### Ethics Approval
This study was approved by the University of Missouri Institutional Review Board (2017125) and registered on ClinicalTrials.gov (NCT04632628).

### Results

#### Stage 1a: Explore Stakeholder Views and Focus Groups

**Advisory Panel**
The advisory panel advised streamlining NiteCAPP content, eliminating jargon, and including caregiver-focused content.

**Focus Group**
For the focus group, average ratings for NiteCAPP features were high (see Table 3), with ratings ranging from 4.21 of 5 to 4.82 of 5 across all measured items.

Common themes included written material, audiovisual material, moderator feedback, and aesthetics of the website. Examples of comments on written materials included: “Easy to read and understand, but should have font size options,” “Great content but written at a pretty high literacy level,” and “Some sentences had too many clauses or more than one idea.” Focus group members stated that the audiovisual materials had “great information,” “were good...[and] engaging,” but should be “captioned or have a header.” NiteCAPP was then updated to incorporate suggestions for improvement based on common themes and titled NiteCAPP CARES (see Table 4). After that update, NiteCAPP CARES was pilot-tested in stage 1b.
Table 3. Stage 1a focus group usefulness ratings (n=5 dementia caregivers; n=5 dementia primary care providers). Scores based on a scale from 0 to 5, with higher scores indicating more favorable ratings.

<table>
<thead>
<tr>
<th>Features</th>
<th>Minimum-Maximum score</th>
<th>Mean score, (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Website</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of use</td>
<td>4.23 (1.40)</td>
<td>3-5</td>
</tr>
<tr>
<td>Amount of info</td>
<td>4.40 (1.16)</td>
<td>2-5</td>
</tr>
<tr>
<td>Maintains interest</td>
<td>4.24 (0.53)</td>
<td>4-5</td>
</tr>
<tr>
<td>Font size</td>
<td>4.82 (0.79)</td>
<td>3-5</td>
</tr>
<tr>
<td><strong>Videos</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain interest</td>
<td>4.21 (0.89)</td>
<td>3-5</td>
</tr>
<tr>
<td>Easy to understand</td>
<td>4.40 (1.00)</td>
<td>3-5</td>
</tr>
<tr>
<td>Helpful</td>
<td>4.44 (0.98)</td>
<td>3-5</td>
</tr>
</tbody>
</table>

Table 4. Stage 1a focus group feedback.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Themes</th>
<th>CG&lt;sup&gt;a&lt;/sup&gt; and PCP&lt;sup&gt;b&lt;/sup&gt; quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Written material</strong></td>
<td>Thorough for target group, Promotes independent completion of intervention, Therapist moderator visual feedback helpful.</td>
<td>&quot;Easy to read and understand, but should have font size options.&quot; [CG-001]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Information broken down into easy to digest chunks and not overwhelming to read through.&quot; [CG-005]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;I like the sense that one could complete these modules independently.&quot; [PCP-001]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Minimize clinical/diagnostic terms.&quot; [PCP-001]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;I think incorporation of graphs and charts for sleep feedback is awesome.&quot; [PCP-002]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Change the word ‘homework’ to something less stressful.&quot; [CG-003]</td>
</tr>
<tr>
<td><strong>Audiovisual material</strong></td>
<td>Rich, engaging information, Important communication tool for target population, Good pacing</td>
<td>&quot;Great information!&quot; [CG-003]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;The videos were good, and I found them to be engaging.&quot; [PCP-004]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;The videos feel a bit hidden, hard to find. Having a tab with all videos might be an option.&quot; [CG-005]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;I think videos are integral to the program. I think her pace is probably good for this patient population, since they will not have heard most of this before.&quot; [PCP-002]</td>
</tr>
<tr>
<td><strong>Aesthetics</strong></td>
<td>Good use of visual contrast</td>
<td>&quot;Have a dark mode or night mode option, will help user’s eyes, especially if using at night.&quot; [CG-005]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Bolding specific words and phrases helps make information accessible.&quot; [CG-005]</td>
</tr>
<tr>
<td><strong>Navigation</strong></td>
<td>Good layout and use of links-tabs to intervention material</td>
<td>&quot;Good links to other sessions and lessons.&quot; [CG-001]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;It’s a lot to navigate on mobile.&quot; [CG-005]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Caregivers are exhausted and need things in small allotments...devices this will be viewed on are smaller in terms of landscape and how one moves beyond the initial screen.&quot; [PCP-001]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Have collapsible tabs that can be expanded/collapsed when necessary to help people scrolling on their phone.&quot; [CG-005]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;I think the pages could also benefit from drop down menus to hide information and have text appear when the user clicks on it. It might make the pages less cluttered and feel more interactive.&quot; [PCP-003]</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
<td>Lack of glossary</td>
<td>&quot;Build in a glossary or a ‘terms to know’&quot; [CG-003]</td>
</tr>
</tbody>
</table>

<sup>a</sup>CG: caregiver.  
<sup>b</sup>PCP: primary care provider.
Stage 1b: Testing Feasibility and Preliminary Effectiveness

Feasibility and acceptability were excellent, with high average completion (>100% of sessions), adherence (76% for sleep hygiene, 80% for stimulus control, and 81% for relaxation based on daily logs), satisfaction (>8.4/10 on the Satisfaction Survey; see Table 5), and usefulness ratings (>4.3/5 on the Internet Intervention Utility Questionnaire; see Table 6). As shown in Table 7, NiteCAPP CARES led to improvements in subjective sleep (sleep onset latency, wake after sleep onset, sleep efficiency, and the Insomnia Severity Scale), arousal, mood (depression), burden, quality of life, perceived stress, and subjective cognition.

Table 5. Stage 1b pilot test satisfaction ratings (n=5 caregivers with insomnia). Scores based on a scale from 0 to 10, with higher scores indicating more favorable ratings.

<table>
<thead>
<tr>
<th></th>
<th>Mean score (SD)</th>
<th>Minimum-Maximum score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected experience</td>
<td>7.44 (3.98)</td>
<td>1-10</td>
</tr>
<tr>
<td>Scheduling convenience</td>
<td>9.03 (1.73)</td>
<td>7-10</td>
</tr>
<tr>
<td>Surveys and forms tolerable</td>
<td>8.49 (1.73)</td>
<td>7-10</td>
</tr>
<tr>
<td>Daily diaries tolerable</td>
<td>8.54 (1.41)</td>
<td>7-10</td>
</tr>
<tr>
<td>Therapist moderator</td>
<td>8.04 (1.41)</td>
<td>7-10</td>
</tr>
<tr>
<td>Recommend to a friend</td>
<td>9.05 (1.41)</td>
<td>7-10</td>
</tr>
</tbody>
</table>

Table 6. Stage 1b pilot test usefulness ratings (n=5 caregivers with insomnia). Scores were based on a scale from 0 to 5, with higher scores indicating more favorable ratings.

<table>
<thead>
<tr>
<th></th>
<th>Mean score (SD)</th>
<th>Minimum-Maximum score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Website</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of use</td>
<td>4.50 (0.83)</td>
<td>3-5</td>
</tr>
<tr>
<td>Amount of info</td>
<td>4.33 (0.55)</td>
<td>4-5</td>
</tr>
<tr>
<td>Maintains interest</td>
<td>4.29 (0.84)</td>
<td>3-5</td>
</tr>
<tr>
<td>Font size</td>
<td>4.32 (0.50)</td>
<td>4-5</td>
</tr>
<tr>
<td>Videos</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain interest</td>
<td>4.13 (0.84)</td>
<td>3-5</td>
</tr>
<tr>
<td>Easy to understand</td>
<td>4.40 (0.89)</td>
<td>3-5</td>
</tr>
<tr>
<td>Helpful</td>
<td>4.18 (0.89)</td>
<td>3-5</td>
</tr>
</tbody>
</table>

Following this pilot test, additional participant qualitative feedback (see Table 8) was used to update NiteCAPP CARES a third time. Participants stated that the written and audiovisual materials were clear, though audiovisual materials were repetitive. Comments and suggestions included moving relaxation techniques to the morning and the importance of a schedule. Therapist moderator feedback was used to refine the guided web-based support and develop a moderator manual with clear, step-by-step instructions, schedule for administration of support, and case examples (see Textbox 1).
Table 7. Stage 1b pilot results. Caregiver subjective sleep, arousal, mood, burden, and cognition (n=5). Measures collected electronically.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Base to post</th>
<th>Effect size</th>
<th>P value</th>
<th>t test (df)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjective sleep</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep onset latency (min)</td>
<td>23.2 (8.67)</td>
<td>1.46</td>
<td>.01</td>
<td>4.01 (4)</td>
</tr>
<tr>
<td>Wake after sleep onset (min)</td>
<td>54.95 (23.03)</td>
<td>1.50</td>
<td>.01</td>
<td>4.05 (4)</td>
</tr>
<tr>
<td>Sleep efficiencyb (%)</td>
<td>79.64 (9.92)</td>
<td>1.46</td>
<td>.02</td>
<td>3.35 (4)</td>
</tr>
<tr>
<td>Insomnia Severity Indexc</td>
<td>15.20 (4.09)</td>
<td>0.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjective arousal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Stress Index</td>
<td>25.40 (5.50)</td>
<td>0.58</td>
<td>.05</td>
<td>2.09 (4)</td>
</tr>
<tr>
<td>Kingston Stress Scale</td>
<td>20.60 (3.65)</td>
<td>0.63</td>
<td>.08</td>
<td>1.73 (4)</td>
</tr>
<tr>
<td>DBASéd</td>
<td>130.80 (30.47)</td>
<td>1.28</td>
<td>.01</td>
<td>3.87 (4)</td>
</tr>
<tr>
<td>Health or mood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BDI-IIf</td>
<td>11.80 (4.32)</td>
<td>1.21</td>
<td>.02</td>
<td>2.89 (4)</td>
</tr>
<tr>
<td>STAIlf</td>
<td>61.40 (11.08)</td>
<td>0.34</td>
<td>.12</td>
<td>1.36 (4)</td>
</tr>
<tr>
<td>Burden</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zarit Burden Scale</td>
<td>23.40 (9.74)</td>
<td>0.48</td>
<td>.05</td>
<td>2.16 (4)</td>
</tr>
<tr>
<td>CG-QOLg</td>
<td>51.00 (19.81)</td>
<td>0.55</td>
<td>.04</td>
<td>2.33 (4)</td>
</tr>
<tr>
<td>Subjective cognition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFQhb</td>
<td>43.80 (14.38)</td>
<td>0.29</td>
<td>.04</td>
<td>2.44 (4)</td>
</tr>
<tr>
<td>Interpersonal processes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCFUSi</td>
<td>39.20 (13.52)</td>
<td>0.09</td>
<td>.28</td>
<td>0.64 (4)</td>
</tr>
</tbody>
</table>

aWithin-group effect sizes based on Hedges $g_{av}$. Values of .20=small, .50=moderate, and .80=large.
bSleep efficiency: ratio of time spent sleeping/time in bed×100%.
cInsomnia Severity Index: 0=none, 28=severe.
dDBAS: Dysfunctional Attitudes and Beliefs about Sleep.
eBDI-II: Beck Depression Inventory-II.
fSTAI: State Trait Anxiety Inventory.
gCG-QOL: Dementia Patient’s Caregiver Quality of Life.
hCFQ: Cognitive Failures Questionnaire.
iPCFUS: Patient-Caregiver Functional Unit Scale.

Table 8. Stage 1b caregiver evaluation comments.

<table>
<thead>
<tr>
<th>Feature</th>
<th>PCG³ quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written material</td>
<td>• “It was clear and easy to understand.” [PCG-01]</td>
</tr>
<tr>
<td></td>
<td>• “I think it is straightforward and easy to understand.” [PCG-04]</td>
</tr>
<tr>
<td>Audiovisual material</td>
<td>• “They were clear but somewhat repetitive.” [PCG-02]</td>
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<tr>
<td></td>
<td>• “I think they are well done and easy to understand.” [PCG-04]</td>
</tr>
<tr>
<td>Comments or suggestions</td>
<td>• “The questions about using the relaxation techniques that particular night should be moved to the a.m. questionnaire sleep diary in the morning.” [PCG-05]</td>
</tr>
<tr>
<td></td>
<td>• “As a caregiver for someone with dementia and a livestock owner, it’s difficult to maintain a set schedule.” [PCG-01]</td>
</tr>
<tr>
<td></td>
<td>• “This is a useful tool for a caregiver in conjunction with methods to get the care partner to sleep on a schedule.” [PCG-03]</td>
</tr>
</tbody>
</table>

³PCG: pilot-test caregiver.
Textbox 1. NiteCAPP CARES stage 1b pilot-test moderator feedback.

Moderator feedback to incorporate
- A clear schedule for therapist moderator notes (eg, a set schedule of when to complete notes and send them to participants)
- A manual with templates for moderator notes for each stage of the study.
- Automated emails informing the moderator when a participant finishes a particular assignment
- Automated reminders for participants to complete diaries

Discussion

Overview

This study used mixed methods of qualitative and quantitative expert (PCPs) and participant-focused (rural dementia caregivers) feedback to iteratively adapt a 4-session web-based CBT-I (NiteCAPP) into a tailored digital format with standard CBT-I content plus caregiver-focused modifications (NiteCAPP CARES). The usability and acceptability of NiteCAPP CARES were then evaluated. The website was evaluated as easily accessible and useful, and the feasibility of the web-based intervention was high, suggesting that NiteCAPP CARES is highly functional for rural caregivers and PCPs. Preliminary efficacy testing also indicated that NiteCAPP CARES improved subjective sleep as well as several key aspects of daily functioning (eg, arousal, mood, burden, and subjective cognition).

Consistent with our hypotheses, the acceptability and usability of NiteCAPP CARES were high. In comparison to other in-person or telehealth versions of CBT-I [61-64], NiteCAPP CARES may offer unique advantages for treating insomnia, particularly in dementia caregivers. For example, NiteCAPP CARES provides greater caregiver accessibility given their demanding schedules since caregivers can access the materials on their schedule without having to make any appointments. NiteCAPP CARES is also less burdensome for both the patient and the therapist moderator, as trained behavioral sleep therapists who can conduct in-person or telehealth CBT-I are in short supply [8]. Further, compared to other web-based insomnia treatments [65-69], NiteCAPP CARES provides important enhancements for older caregivers. For example, although other 5 to 6–session, web-based CBT-I platforms [65,66] provide audiovisual content, NiteCAPP CARES provides tailored audio and visual recommendations for dementia caregivers. In addition, unlike other web-based CBT-I platforms, NiteCAPP CARES also provides a help forum to provide 24-7 assistance from therapist moderators. Other web-based CBT-I platforms [67] use sleep diaries and have a clinician and patient portal but function as adjuncts to in-person treatment, whereas NiteCAPP CARES is a standalone moderated treatment that allows the caregiver to access all the materials on their schedule. Other web-based CBT-I platforms [68,69] offer 6 sessions with tailored sleep recommendations based on either sleep diaries or screening questionnaires. One web-based CBT-I [69] even provides a web-based therapist who advises the patient on restructuring their cognitions, but this feedback does not extend to the patient’s sleep. However, none of these web-based insomnia treatments provide a simpler interface tailored for older caregivers or provide tailored and moderated therapy throughout treatment. In addition, the NiteCAPP CARES website itself was rated very highly in terms of its ease of use and readability (eg, font size), which were part of its initial user-centered design that took age-related cognitive or perceptual concerns in our target population into consideration (see Methods section) [70-74]. Second, caregiver use was likely promoted through the use of nonstructured session times (caregivers were encouraged to complete the sessions on their own schedule), simplified language, videos, and pictographs.

As expected, preliminary results also reveal that NiteCAPP CARES shows promise for improving the majority of our key outcomes. The moderate to large improvements across sleep outcomes (sleep onset latency, wake after sleep onset, sleep efficiency, and insomnia severity) found for NiteCAPP CARES are similar or greater than those found for other web-based CBT-I platforms [65,66,69]. Extending findings from previous web-based CBT-I interventions, our preliminary results also provide novel findings regarding NiteCAPP CARES’ potential impact on stress or arousal and subjective cognition (a treatment outcome that has not previously been assessed). NiteCAPP CARES showed improvements in subjective arousal (moderate to large effects) and cognition (small effects), as well as burden (small to moderate effects). Unlike other web- and app-based CBT-I platforms [65-69], the use of a therapist moderator was noted as a positive feature of the intervention during pilot-testing and likely contributed to its acceptance and high completion rate. Previous completion percentages of therapist-led CBT-I treatment range from 63% to 88% [61,62] for telehealth treatment and 80% to 98% [63,64] for in-person treatment, both below NiteCAPP CARES’ 100%. Similarly, average treatment adherence for therapist-led CBT-I is 38% and digital CBT-I is 35%, both lower than NiteCAPP CARES’ 76%-81% [75]. NiteCAPP CARES suggests that moderated web-based interventions may be comparable to or surpass the completion rates for in-person and telehealth delivery of CBT-I in this population. This will provide increased accessibility for caregivers living in rural areas that are not close to health care providers.

Clinical Implications

Although further testing of NiteCAPP CARES is currently underway [76], these preliminary findings potentially suggest several clinical implications. Improving caregiver sleep is critical given that caregiver insomnia is associated with negative changes in central stress processing, resulting in poor physical health (altered heart rate and heart-rate variability) [77] and mood (anxiety and depression) [18,78]. Insomnia is also associated with poor caregiver cognition (processing speed
Limitations and Future Directions

This study provides a foundation for future sleep research in rural dementia caregiver populations, which have largely been ignored. Our study has several limitations. First, the small number of individuals in our focus group and pilot test may not generalize to a broader population of caregivers and PCPs. Similarly, our small sample may have inflated our effect sizes; however, our previous studies in similar populations have shown these effect sizes to be robust [18,20,36]. Future studies should include a larger sample size that includes individuals from many different facets of life. For instance, it would be beneficial to gain insight from people with dementia, as NiteCAPP CARES treatment modules can be expanded to include resources specific to the care recipient. Furthermore, it would also be important to seek more evaluation from health care administration teams, who are likely to be the ones to give patients step-by-step instructions on how to log in and navigate NiteCAPP CARES. Future studies should focus on gaining feedback from dementia patient advocates, who have a considerable amount of insight on how to effectively care for and work with people with dementia and caregivers. The promising results from this preliminary development and initial evaluation study suggest a future randomized controlled trial that examines the efficacy of NiteCAPP CARES compared to an active web-based control in a larger sample of rural dementia caregivers is an important and warranted next step. Such future work may also benefit from a tailored, dyadic approach that involves the person with dementia in the treatment to the extent they are capable. Following further development and the establishment of efficacy, additional future steps include an effectiveness trial and broader implementation and dissemination efforts, as well as the development of a web-based, stand-alone sleep treatment for dementia caregivers. Specifically, as noted above, NiteCAPP CARES’s moderated web-based intervention provided excellent adherence and engagement compared to completion rates for other web-based treatments [58-61]. While this preliminary study’s results support our use of a moderated approach, a web-based, stand-alone option may be preferred by some caregivers and would provide them with an additional access option for obtaining CBT-I.

Conclusions

A brief, web-based CBT-I platform called NiteCAPP CARES was created for caregivers to address caregiver sleep issues. Initial website feedback was accessed by asking rural caregivers and PCPs their opinions on NiteCAPP CARES. They thought the site was easy to understand, engaging, and well designed. Preliminary pilot-test data indicated that caregivers used the site (high treatment adherence and session completion), found it useful, and reported high satisfaction. NiteCAPP CARES also improved subjective sleep and daily functioning. These promising outcomes suggest that NiteCAPP CARES can be a beneficial sleep tool for both rural dementia caregivers and health care providers. Underserved populations who have difficulty obtaining evidence-based health care may particularly benefit from NiteCAPP CARES given its web-based delivery, which can be accessed anywhere the internet is available. A future randomized controlled trial to evaluate NiteCAPP CARES compared to an active web control in a larger sample is needed.

Acknowledgments

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Authors’ Contributions

All authors made substantial contributions to the concept and design of the study. CSM and AFC drafted the initial study design with input from all authors. MG, NN, and AFC conducted statistical analysis. CSM and DQB drafted screening procedures. DQB, JIS, AC, and MAR drafted recruitment and referral procedures. CSM, AFC, and MAS drafted the manuscript. All authors reviewed and approved the revised manuscript.

Conflicts of Interest

None declared.

References


Abbreviations

CBT-I: cognitive behavioral therapy for insomnia
PCP: primary care physician
Development and Initial Evaluation of Web-Based Cognitive Behavioral Therapy for Insomnia in Rural Family Caregivers of People With Dementia (NiteCAPP): Mixed Methods Study

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A Perspective on Using Virtual Reality to Incorporate the Affective Context of Everyday Falls Into Fall Prevention

Tiphanie E Raffegeau¹, DPhil; William R Young², DPhil; Peter C Fino³, DPhil; A Mark Williams⁴, DPhil

¹School of Kinesiology, George Mason University, Manassas, VA, United States
²School of Sport and Health Sciences, University of Exeter, Exeter, United Kingdom
³Department of Health and Kinesiology, University of Utah, Salt Lake City, UT, United States
⁴Health, Performance, and Resilience Group, Institute of Human and Machine Cognition, Pensacola, FL, United States

Corresponding Author:
Tiphanie E Raffegeau, DPhil
School of Kinesiology
George Mason University
10890 George Mason Circle
201G Katherine G Johnson Hall
Manassas, VA, 20110
United States
Phone: 1 7039937000
Email: trafge@gmu.edu

Abstract

Virtual reality (VR) is a promising and cost-effective tool that has the potential to reduce the prevalence of falls and locomotor impairments in older adults. However, we believe that existing VR-based approaches to prevent falls do not mimic the full breadth of perceptual, cognitive, and motor demands that older adults encounter in daily life. Researchers have not yet fully leveraged VR to address affective factors related to fall risk, and how stressors such as anxiety influence older adult balance and real-world falls. In this perspective paper, we propose developing VR-based tools that replicate the affective demands of real-world falls (eg, crossing the street) to enhance fall prevention diagnostics and interventions by capturing the underlying processes that influence everyday mobility. An effort to replicate realistic scenarios that precipitate falls in VR environments will inform evidence-based diagnostics and individualize interventions in a way that could reduce falls in older adults in daily life.

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KEYWORDS

aging; balance; perturbation; locomotion; cognition; exergame; anxiety

Introduction

Annually, 1 in 4 older adults are injured from falling [1], and the incidence rates [2] and resulting morbidities continue to rise [3]. Alongside rapidly advancing virtual reality (VR) technology, scientists and clinicians are working to predict and prevent falls using a range of nonimmersive and immersive techniques [4-6]. Yet, researchers are only beginning to understand the potential benefits of VR technologies and their capabilities to target the perceptual, cognitive, and motor processes related to fall risk [7]. We believe there is a disconnect between how VR is currently used to understand and prevent falls in experimental settings and its capacity to identify and target the processes that are involved when older adults fall in daily life.

We argue that scientists currently using VR technology to evaluate and modify fall risk often overlook stressors such as anxiety or the “fear of falling” that are associated with higher prevalence of falls [8,9]. As we age, we use more attentional capacity while walking and stepping becomes less “automatic” [10]; thus, the added cognitive demand of fear of falling could be detrimental to balance and gait for older people [11-14]. Our underlying argument is that the context of balance control is important, and scientists should aim to create paradigms that better replicate the challenges that older adults experience during everyday walking to understand and prevent falls. By not representing the affective context that exists in the real world in VR-based tasks and interventions, we fail to address the interactions between perceptual, cognitive, and motor processes that underlie effective or maladaptive balance in daily life [15-18]. Scientists now have a unique opportunity to develop VR-based tools that facilitate interactions with realistic mobility contexts that induce anxiety as in the real world (eg, crossing a busy street at night and walking in a crowded mall). By using...
VR to engage with realistic contexts, we could better identify older adults who are most at risk of falling and develop refined interventions to prevent falls.

Our overarching interests are to establish early diagnostics that identify who is at greatest risk of falling and develop specific interventions that reduce the risk of falls in everyday life. In this perspective paper, we discuss leveraging the rising popularity of VR to develop meaningful protocols for diagnosing and treating the risk of falling in older adults. Specifically, we discuss how VR simulations can recreate the typical perceptual, cognitive, motor, and affective demands of daily life to facilitate diagnostics and interventions that reduce the risk of falling. The key points discussed in this paper are shown inTextbox 1.

Textbox 1. Key points discussed in this perspective.

- Scientists should aim to better replicate the challenges that older adults experience during everyday walking to understand and prevent falls.
- We do not yet know if the experimental outcomes emerging from laboratory-based studies are representative of behavior in everyday life. However, virtual reality (VR) technology allows us to probe mobility-related affective responses with threats to stability and balance control.
- VR can simulate everyday situational demands and quantify responses with high resolution, thereby helping to bridge the gap between laboratory-based research outcomes and everyday fall risk.
- We propose a focus on scenarios where older individuals experience a fear of falling to identify associated deficits in perceptual, cognitive, and motor processes.
- To better detect everyday fall risk, scientists should incrementally challenge sensory, motor, and cognitive systems using a contextually appropriate VR-based stress test for fall risk.
- Using VR to address individual differences by measuring learning trajectories allows for tailored challenge points and appropriate difficulty levels that optimize learning.
- VR therapies successfully reduce anxiety in younger people; it is not hard to imagine a future where VR could help older adults overcome a fear of falling and cope with mobility-related anxiety.

The Problem: Research on Fear of Falling and Fall Risk in Older Adults

As a result of poor “balance confidence” or low “falls efficacy,” many older adults report a “fear of falling” and experience mobility-related anxiety during locomotion [16]. We provide a brief overview of how fear and anxiety influence fall risk (ie, the physiological and cognitive response to a perceived threat in a balance or walking task). We refer the reader elsewhere for detailed reviews that distinguish these processes from concepts such as concern about falling [13,16,18]. Older adults who experience a fall are more likely to exhibit gait impairments and suffer higher incidents of falling [19,20]. We define “mobility-related anxiety” as a phobia specific to walking that is associated with increased physiological arousal and cognitive stress, which interferes with perceptual, cognitive, and motor processes during walking in young and older adults [12,21-24]. Both self-reported fear of falling and mobility-related anxiety are believed to impair cognitive-motor control, predisposing older adults to a greater risk of slips, trips, and falls [13,14,18]. However, there may be some protective element to mobility-related anxiety, encouraging older adults to compensate for poor balance by “consciously monitoring” their actions in efforts to remain safe [17]. The degree that mobility-related anxiety impedes or protects older adult balance is still unclear because current evidence is only supported by cross-sectional associations between fear of falling and motor outcomes [25], fall incidences [26], or anxiety-related responses from experimental manipulations (eg, raising participants on a platform) [11,23,27]. The experimental tasks used by scientists and clinicians are strictly controlled, and consequently, these tasks may not induce anxiety in a way that represents the anxiety-inducing experiences of older adults in real-world mobility scenarios (eg, crossing a busy street at night). We argue that scientists should leverage advances in technology to develop representative mobility tasks within VR simulations while simultaneously retaining experimental control. VR presents an ideal tool to create realistic contexts that would enhance and individualize fall-risk detection and prevention.

Current Ways to Use VR to Study Mobility-Related Anxiety

Scientists interested in the effects of anxiety on mobility have predominantly used VR to create controlled experiments that answer fundamental science questions. Unfortunately, often the experimental conditions induced have limited relation to situations encountered in daily life. For example, our previous work has shown that immersive VR can be used to increase mobility-related anxiety in healthy people by simulating standing on a wooden plank and raising the walkway approximately 15 meters above ground level [24,28]. Although our approach allowed us to answer important questions about anxiety and motor control, we are hesitant to equate our results to behaviors in daily life. Historically, obtaining results that are representative of everyday tasks, or “representative task design,” has been a persistent limitation across many fields [29,30]. We do not yet know if the experimental outcomes emerging from controlled, laboratory-based studies are representative of behavior in everyday life. However, existing VR technology lends itself to probing affective responses by systematically imposing mobility-related threats to stability and testing balance control across external task constraints.

Scientists have typically used VR to induce mobility-related anxiety by replicating laboratory-based studies that physically raise participants to elevated heights [23,27,31]. The aim is to stimulate affective systems by increasing the perceived consequences of falling, also known as “postural threat” [23,31].
Simulating elevated heights in VR elicits similar changes to state anxiety (ie, subjective ratings) and motor behavior (ie, smaller postural sway area) as in the real world [32-34]. Various types of threatening contexts can elicit anxiety-related responses, ranging from simulated heights in a replicated laboratory environment [33,35,36] to riding an open elevator [37] and walking across a deep pit [38,39].

Another approach to study mobility-specific anxiety is to increase the difficulty of the locomotor task by walking on a narrow path. By increasing attentional demand and the energy cost of gait patterns [40,41], a narrower path imposes a demanding locomotor constraint that requires participants to continuously adapt and monitor their steps. A narrower step width also involves intrinsic risk appraisal by challenging stability; participants must evaluate their balance and devote additional attentional resources to compensate for their anticipated missteps [42]. We interpret the added cognitive load of taking narrower steps as analogous to the “conscious monitoring” experienced by older adults who are anxious while walking [13,43].

VR-based tools can combine environmental and task-specific influences on mobility-related anxiety, emphasizing their potential to systematically examine the interactions between key perceptual, cognitive, and motor behaviors. Walking in VR on broad and narrow roads, and at low and high elevations, can reveal complex interactions between anxiety, cognition, and motor behavior in young and older adults [44]. For instance, combining path width and height manipulations in VR increases motor difficulty in addition to multiplying to consequences of a fall, forcing participants to prioritize performing the task safely versus quickly, revealing the interactions between mobility-related anxiety and motor performance [44]. Challenging balance in threatening VR environments (an increasingly narrowing path) reveals that balance confidence mediates the efficacy of older adults’ stepping responses [45,46]. Cumulatively, these results highlight the salience of mobility-related anxiety in locomotor behavior and its potential importance in improving balance and reducing fall risk.

However, while VR has led to advances in understanding mobility-related anxiety and balance, there remains a disconnect between experimental manipulations of anxiety responses and the lived experience of older adults suffering from mobility-related anxiety in daily life. We propose that researchers use VR to simultaneously test the influence of task- and environmentally driven affective responses on locomotion, while working to develop generalizable applications. We envision VR could be used as a tool to generate outcomes that are experimentally controlled, while simultaneously being representative of everyday contexts that precipitate real-world falls.

**Current Ways to Use VR-Based Technology for Fall Prevention**

**Overview**

While our perspective details ways to enhance the application of VR for fall prevention, existing empirical evidence already supports the use of VR-based tools for preventing falls in older adults. We overview the current use of VR technology in fall-prevention research with reference to the following three general categories of current technology: (1) nonimmersive VR; (2) augmented reality (AR); and (3) immersive VR. We consider the advantages and disadvantages of each approach with regard to older adult fall prevention.

**Nonimmersive VR**

The majority of published reports focusing on the benefits of VR-based tools in older adult fall prevention use nonimmersive devices that range in design and application [47-54]. Nonimmersive technology typically delivers a gamified rehabilitation goal and provides 2D visual feedback of body position or motor performance on a television display. Position detection capabilities vary and include simpler platform or controller-based devices, such as a Wii balance board or Wii Fit (Nintendo), as well as optical tracking systems ranging from the X-box Kinect (Microsoft) to high-speed infrared cameras using expensive motion capture techniques such as the CAREN (Motek). Visual stimuli range from a low-cost flat-screen television presented at eye level [55] to digital projections onto a treadmill belt [56], to a 180 curved floor-to-ceiling projection screen [45,57,58]. Interactions within VR afford many options for providing biofeedback [59], where the majority of nonimmersive video games present both feedback of body position and knowledge of performance outcomes [6,55]. However, a lack of consistency in delivery and application of visual biofeedback in immersive VR [24,38,60] makes it difficult to determine if nonimmersive therapeutic protocols and positive effects are replicable or might be enhanced with advanced technology [61,62]. One significant issue relating to standardization of protocols relates to limited accessibility, as many nonimmersive VR tools are no longer commercially available. Nonimmersive VR applications therefore require custom programming, rendering the product commercially unscaleable and only suitable for research purposes.

**Augmented Reality**

AR, or mixed reality, is a unique technology with great potential to train balance and reduce falls using ecologically valid locomotor tasks. AR overlays 3D virtual illusions through interactive games within the individual’s real-world setting, typically using face-worn eyeglasses or goggles. Integrating the game into the real-world setting and feedback of oneself likely enhances the “task specificity” of AR-based tools for transferring performance to real-world balance and gait tasks [63]. AR has also shown promise in providing social interaction and psychological support for older people; its primary advantage for health-related applications may be its capacity to increase motivation to engage in physical training [63,64]. Perhaps a result of shifting gaze to look at or look through a peripheral display, lateral stability is compromised by AR glasses [65], which may be particularly detrimental for older adult fallers who are worse at controlling mediolateral balance [66]. AR technology shows great promise for everyday fall prevention, but development is lagging with respect to user-friendly programming and commercial accessibility, especially for older adults [63].
**Immersive VR**

Typically delivered via a head-worn virtual display, or head-mounted display (HMD), immersive VR replaces one’s current setting with an interactive 2D (eg, video-based) or 3D (eg, digitally rendered) environment. By blocking out sensory feedback from the outside world, immersive VR presents an opportunity to stimulate sensory, and motor systems for fall prevention. Advances in graphic design and rendering capabilities have drastically improved the realism of immersive VR simulations and multiplied the potential experiences representative of daily life. Impaired older adults (ie, immobile or cognitively impaired) can experience 2D images using an HMD (usually video-based stimuli), without negative side effects such as motion sickness [67]. An HMD obstructs visual feedback of body position without added accessories or specific game development, which influences the control of basic perception and action [68] and locomotor control in VR simulations [62]. We speculate that ongoing bodily feedback may be a key difference between immersive and projection-based treadmill VR environments, facilitating a greater sense of immersion (measured as self-reported “presence”) during an elevated height simulation [69,70], and higher levels of reported anxiety in projection-based approaches when compared to an immersive HMD [71,72]. Table 1 presents the advantages and disadvantages of different VR types to prevent falls.

<table>
<thead>
<tr>
<th>VR types</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Nonimmersive VR</td>
<td>• Feasible for use with older adults in community settings [51] and people with Parkinson disease [73] • Benefits impaired populations such as stroke survivors [74,75] and people with Parkinson disease [76,77] • Interventions improve performance on physical function tests related to fall risk [52,53,78], reduce fear of falling and depression [79,80], and reduce the incidence of falls in frail older adults [78] • Can replicate balance perturbation training techniques with visual perturbations [35,58] that improve balance recovery and reduce real-world falls [81,82].</td>
<td>• A lack of consistency in delivery or application of visual biofeedback (ie, displaying motor performance versus results, or both) make it difficult to determine if therapeutic results are replicable • Most nonimmersive VR equipment is no longer commercially available and requires custom programming that is only suitable for research purposes</td>
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<tr>
<td>AR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>• AR interactions take place in everyday settings and can serve as realistic substitutes for environmental manipulations or cues. Placing AR obstacles in one’s path simulates the task of avoiding them as if they existed in reality, but without the trip hazard [83] • AR-based visual and audio cues often improve gait characteristics in people with neurological conditions, particularly people with Parkinson disease [84]</td>
<td>• Lateral stability is compromised by AR glasses [65], which may be particularly detrimental for older adults prone to falling or those with deficits in controlling mediolateral balance [66] • Older adults report current AR goggles as heavy and uncomfortable during balance training [85], an issue that could be addressed by forthcoming technology mimicking traditional spectacles • Development is lagging with respect to user-friendly programming and commercial accessibility, especially for older adults [63]</td>
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<tr>
<td>Immersive VR</td>
<td>• Can systematically implement visual perturbations (ie, shifting the room suddenly) that induce a sensation of falling [86], leading to a decline in stability and forcing older adults to practice and train reactive balance recovery in a safer way [87,88] • Using immersive VR to manipulate visual input during clinical physical function tests better detects fall risk [89]</td>
<td>• Immersive HMD&lt;sup&gt;b&lt;/sup&gt; technology can be difficult to operate [90] • Bulky and uncomfortable to wear [91] • Limiting the visual field of view [92] • Sometimes causing motion sickness [93] that could be interpreted as a sign of a potential fall by at-risk older adults • HMDs obstruct visual feedback of body position without added hardware or customized programming to track body position. The absence of visual feedback influences basic perception and action [68], locomotor control [62], and interactions between anxiety and motor control in anxiety-inducing VR simulations [94]</td>
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<sup>a</sup>AR: augmented reality.

<sup>b</sup>HMD: head-mounted display.

**Incorporating the Context of Everyday Falls Into Fall Prevention**

Rehabilitation scientists are limited in their ability to replicate complex everyday scenarios and elicit representative anxiety, hindering the ecological validity and translation of existing approaches. Simultaneously, we have yet to find a way to measure perceptual, cognitive, and motor processes in the real world without using disruptive and resource-heavy equipment. To address both limitations, VR can simulate everyday situational demands and quantify responses with high resolution,
thereby helping to bridge the gap between laboratory-based research outcomes and everyday fall risk. As opposed to evaluating physical function in sterile clinical settings with clear hallways, using VR to challenge older adult mobility within an ecologically valid setting would better reveal real-world mobility deficits, thereby potentially leading to enhanced therapies to reduce fall risk.

Crossing the street at night is an example of a locomotor context that elicits a specific mobility-related anxiety and requires effective perceptual (eg, judging the distance to oncoming hazards with low-quality visual feedback), cognitive (eg, gathering and retaining limited visual and spatial information in working memory to monitor position), and motor adaptations (ie, neuromuscular coordination and step targeting) to achieve safely. It may therefore be no surprise that older adults experience a higher prevalence of traffic-related injuries compared to younger pedestrians; a consequence attributed to a host of individual, task, and environmental factors [95], including self-reported fear of falling [96]. The capability of VR-based tools to replicate a street-crossing simulation for older adults was demonstrated in a series of studies using a projection-based room with a 360° simulation of a busy street and crosswalk [97], allowing people to move through a realistic 3D visual surround. The results show when older pedestrians avoid moving traffic, their cognitive-motor “workload” is higher than when crossing an empty street, leading older adults to walk faster and ignore traffic-avoidance–related tasks [98]. These latter behaviors are reminiscent of older adults in artificial anxiety-inducing settings (ie, a narrow or elevated walkway) [44]. A similar study recently used a street-crossing paradigm in an immersive commercial HMD apparatus measuring eye tracking, locomotor behavior, and cognitive performance to draw inferences about pedestrian behaviors in young adults [99]. Such studies highlight the potential to use VR to simulate realistic everyday contexts that challenge affective responses while being feasible for older adult users. We believe further efforts are needed to develop similar immersive, yet effective, VR-based approaches using simulations of real-world contexts where falls are common.

The greater challenge is to capture behavior from fearful older adults during threatening walking scenarios and best use VR to quantify behaviors that perpetuate falls. We propose a focus on scenarios where older individuals experience a fear of falling, especially in settings leading to real-world falls such as stairwells, escalators, crowded sidewalks, shopping malls, or nighttime streets. Borrowing from the concepts developed from successful trauma-focused VR-based treatment of posttraumatic stress disorder (PTSD) in soldiers [99,100], combat scenarios are predictable sources of phobic anxiety. Therefore, presenting a realistic combat scenario in VR is likely to elicit a phobic response. Yet, we cannot be certain which scenarios cause anxiety responses for older adults in real life and how those vary individually. We propose qualitative interview-based inquiry [101], a type of “needs assessment” or “task analysis,” as a step toward determining the scenarios that are anxiety inducing for older adults with motor impairments related to a concern about falling. Our previous qualitative work interviewed fearful older adults to examine their thoughts during hypothetical scenarios leading to falls, and our findings debunked popular theories about attentional focus (ie, attentional control theory) under anxiety or stress developed using data from athletes [102]. Whereas athletes are distracted by a “threat bias” in attentional control that is maladaptive in competitive settings [103], we showed that some degree of “conscious monitoring” drugging walking is protective for older adults who realistically appraise their sense of control in the situation [17]. Only individuals who expressed lacking a sense of control demonstrated a maladaptive fear of falling [17], highlighting the value of qualitative inquiry in translating theory into population-specific interventions.

VR environments that represent everyday situations associated with a fear of falling would allow clinicians to examine locomotor performance on a range of functional tasks in a fall risk “stress test”. Such a virtual “stress test” was recently demonstrated in a functional VR game using an urban scenario designed for rehabilitating activities of daily living [104]. The “UrbanRehab” VR tool was created to optimize ecological validity and challenge outdoor mobility in urban settings to train and enhance movement. The creators of the UrbanRehab program began with a focus group of rehabilitation specialists and aimed to create an environment where patients could be challenged with a variety of different tasks in a realistic cityscape. The challenges and achievements of the UrbanRehab program are reported from a developer’s perspective in further detail [104], highlighting the development-related challenges of designing and implementing realistic VR games for rehabilitation. For example, designing realistic games that enable functional movement is limited by in-home space constraints, presenting a common and difficult challenge that developers must overcome. However, the UrbanRehab initiative represents an exciting first step in realizing the potential for VR to reduce real-world falls.

A major advantage of VR is the capability to address individual differences due to its capacity to change the level of task difficulty and create appropriate “challenge points” or “desirable difficulties” [105]. To better detect everyday fall risk, a range of typical sensory, motor, and cognitive challenge points can be incorporated into a contextually appropriate VR-based stress test for fall risk. For instance, incorporating increasingly physiologically demanding locomotor tasks as challenge points, such as changes in walking speed along a crosswalk, could better reveal fall risk related to poor lower limb strength or power [106] and may be a better predictor of fall risk than measuring walking at comfortable speeds [107]. VR-based challenge points can present increasingly difficult but realistic obstacles for avoidance such as potholes, puddles, or oncoming pedestrians [108], which would better identify people who struggle to maintain balance during complex stepping tasks [109]. Challenging balance control in VR with dynamic locomotor tasks such as turning would reveal deficits in motor control mechanisms that are relevant to everyday falls [110,111]. Using challenge points to progressively manipulate visual flow during walking [46,57] or walking in increasingly low-light settings [112] would flag sensory integration deficits for intervention (ie, proper corrective eye wear, visuo-motor training) before they become a problem [113]. Finally, presenting increasingly complicated but realistic concurrent...
cognitive tasks as challenge points, such as concurrently monitoring a clock or oncoming pedestrians [99], would better identify older people at risk of real-world falls due to cognitive-motoric deficits [114,115]. In sum, VR allows scientists to measure performance across different challenge points, whereby participants are pushed to perform at, or near, the limits of their capability in everyday cognitive-motor performance, highlighting locomotor deficits before they lead to a fall in daily life.

The individual differences in learning outcomes detected across challenge points in diagnostics can optimize VR-based interventions for each learner and lead to enhanced transfer of skills to the real world. VR lends itself to quantifying and adjusting training loads for individual responses to an intervention and augmenting training loads for learners [105]. Commercially available VR systems boast multiple ways to measure performance (eg, eye tracking and kinematics) to achieve goal-related outcomes (eg, a gamified performance goal), and either aspect of a simulation can be tailored to target individual needs and training goals. Advances in data modeling and machine learning allow us to measure individual differences in learning by analyzing changes in performance versus goal-related outcomes (ie, speed versus accuracy analyses) across repeated practice sessions or challenge points. Using VR to quantify individual learning trajectories allows for tailored challenge points and maintaining appropriate difficulty levels [105], and VR-based approaches could adjust training loads to optimize learning for each participant throughout an intervention.

Practitioners are already using VR with younger populations to rehabilitate those with anxiety-related disorders, pioneering a wider application of VR for “exposure therapy” to reduce anxiety [100]. For example, the Bravemind program builds on evidence highlighting that VR-based exposure therapy can reduce depression and anxiety in veteran soldiers with PTSD [116]. Bravemind uses VR to simulate combat-related scenarios in combination with cognitive behavioral therapy, which reframes anxiety-based reactions with “cognitive restructuring,” providing a low-threat context where a patient can therapeutically decondition the cycle of anxiety via habituation [100]. The immersive VR program trains soldiers to compensate and adapt to their PTSD symptoms over time with prolonged exposure to threatening stimuli in VR, guided by evidence from successful VR treatments leveraging exposure therapy for specific phobias [69,117]. Similar exposure effects are reported in VR-based anxiety-inducing settings; the effects of mobility-related anxiety on motor performance (ie, gait speed) decay as participants acclimate to the simulated scenario [23,24], suggesting a similar approach may work to train older adults at risk for maladaptive mobility-related anxiety.

The use of VR-based approaches in conjunction with cognitive behavioral therapy could be effective in reducing fear of falling in older adults [118]. VR-based therapies for treating anxiety disorders are rising in popularity, and meta-analyses support using VR for treating anxiety when compared with traditional therapies [119], especially in preventing patient attrition [119,120]. While no substantive advantages are associated with current VR-based programs compared to traditional therapy, participants are more likely to adhere to VR-based therapies, thus improving their efficacy. We speculate that higher levels of adherence could be a result of greater engagement, which improves motor learning outcomes in gamified rehabilitation programs as compared to the sterility of traditional rehabilitation settings [64]. If VR technology can be refined and harnessed, we believe that the effectiveness (and relative affordability) of such therapies can outperform traditional treatment methods. Because of the success of programs such as Bravemind and the increasingly immersive VR experiences, it is not difficult to imagine a future where older adults are trained to optimize their performance on everyday mobility tasks using controlled exposure to stressful virtual environments.

## Conclusions

VR is an appealing and practical tool to enhance and maintain older adult mobility. We envision a future where realistic contexts for individualized VR-based fall-prevention diagnostics and interventions will reduce the risk of real-world falls in older adults. By incorporating the context of daily tasks into VR-based approaches, we can quantify movement within complex and realistic environments that better represent the demands that older adults navigate every day. Focusing on using VR to mimic the influence of affect on cognitive, perceptual, and motor behaviors should guide industry, researchers, and clinicians toward therapies that prevent everyday falls.

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### Conflicts of Interest

None declared.

### References


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Abbreviations
AR: augmented reality
HMD: head-mounted display
PTSD: posttraumatic stress disorder
VR: virtual reality

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Original Paper

Canadian Older Adults’ Intention to Use an Electronic Decision Aid for Housing Decisions: Cross-sectional Web-Based Survey

Maya Fakhfakh¹², MSc; Virginie Blanchette²³, MSc, PhD, DPM; Karine V Plourde², MSc, PhD; Souleymane Gadio², MSc; Marie Eli¹, RN, MSc, PhD; C Allyson Jones⁴, MSc, PhD; Louise Meijering⁵, MSc, PhD; Anik Giguère²³, MSc, PhD; France Légaré²⁷, MSc, MD, PhD, CCFP

¹Department of Social and Preventive Medicine, Université Laval, Quebec City, QC, Canada
²VITAM – Centre de recherche en santé durable, Centre intégré universitaire de santé et services sociaux de la Capitale-Nationale, Quebec City, QC, Canada
³Department of Human Kinetic and Podiatric Medicine at Université du Québec à Trois-Rivières, Trois-Rivières, QC, Canada
⁴School of Health and Welfare, Dalarna University, Falun, Dalarna, Sweden
⁵Faculty of Rehabilitation Medicine, University of Alberta, Edmondond, AB, Canada
⁶Population Research Centre, Faculty of Spatial Sciences, University of Groningen, Groningen, Netherlands
⁷Department of Family Medicine and Emergency Medicine, Université Laval, Quebec City, QC, Canada

Corresponding Author:
France Légaré. MSc, MD, PhD, CCFP
Department of Family Medicine and Emergency Medicine, Université Laval
Ferdinand-Vandry Pavilion, 1050 Av. de la Médecine
Quebec City, QC, G1V 0A6
Canada
Phone: 1 4186563678
Email: France.Legare@mfa.ulaval.ca

Abstract

Background: Older adults with disabilities such as loss of autonomy face the decision of whether to stay at home or move to a health care facility such as a nursing home. Therefore, they may need support for this difficult decision.

Objective: We assessed the intention of Canadian older adults to use an electronic decision aid (eDA) to make housing decisions and identified the factors that influenced their intention.

Methods: We conducted a cross-sectional study using a web-based survey targeting older adults across 10 Canadian provinces and 3 territories. We included respondents from a web-based panel who were aged ≥65 years, understood English or French, had access to an electronic device with an internet connection, and had made a housing decision over the past few months or were planning to make a decision in the coming year. We based the web-based survey on the Unified Theory of Acceptance and Use of Technology (UTAUT). We adapted 17 UTAUT items to measure respondents’ intention to use the eDA for housing decisions, as well as items measuring 4 intention constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions). We also assessed eHealth literacy using both subjective and objective scales. We used descriptive statistics and multivariable linear regression analyses to identify the factors influencing the intention to use the eDA.

Results: Of the 11,972 invited panelists, 1176 (9.82%) met the eligibility criteria, and 1000 (85.03%) respondents completed the survey. The mean age was 72.5 (SD 5.59) years. Most respondents were male (548/1000, 54.8%), White (906/1000, 90.6%), English speakers (629/1000, 62.9%), and lived in Ontario or Quebec (628/1000, 62.8%) and in urban areas (850/1000, 85%). The mean scores were 27.8 (SD 5.88) out of 40 for subjective eHealth literacy and 3.00 (SD 0.97) out of 5 for objective eHealth literacy. In our sample, the intention score was 4.74 (SD 1.7) out of 7. The mean scores of intention constructs out of 7 were 5.63 (SD 1.28) for facilitating conditions, 4.94 (SD 1.48) for performance expectancy, 5.61 (SD 1.35) for effort expectancy, and 4.76 (SD 1.59) for social influence. In the final model, the factors associated with intention included mother tongue (β=.30; P<.001), objective eHealth literacy (β=-.06; P=.03), performance expectancy (β=.55; P<.001), social influence (β=.37; P<.001), and facilitating conditions (β=.15; P<.001).

Conclusions: Findings from this pan-Canadian web-based survey on Canadian older adults suggest that their intention to use the eDA to make housing decisions is similar to the findings in other studies using UTAUT. The factors identified as influencing
intention were mother tongue, objective eHealth literacy, performance expectancy, social influence, and facilitating conditions. These will guide future strategies for the implementation of the eDA.

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**KEYWORDS**

aged; intention; decision aid; decision support techniques; housing; unified theory of acceptance and use of technology; UTAUT; information technology; internet; shared decision-making

**Introduction**

**Background**

As in many other countries, older adults in Canada (ie, persons aged ≥65 years) are a rapidly growing segment of the population [1]. In Canada, the number of older adults increased by 18.3% between 2016 and 2021 to reach 7 million [2]. By 2030, it is estimated that older adults will account for 23% of the Canadian population [1]. As adults age, they are more likely to experience disabilities, leading to loss of autonomy [3]. For instance, in Canada, 19.5% of older adults reported that their health was perceived to be somewhat worse or much worse than 1 year ago and 16.5% had to receive assistance from family, friends, or neighbors for a health problem or disability. On the basis of the Instrumental and Basic Activities of Daily Living Classification, 93.9% of Canadian older adults experience a mild loss of autonomy [4].

To manage loss of autonomy, meet health care and social services needs, and ensure their safety and well-being, many Canadian older adults consider receiving home care, which typically includes nursing care, therapy (physical, occupational, and speech-language), and medical and social services [5]. Others consider assisted living or moving to residential health care facilities, such as nursing homes [6-8]. In this paper, all decisions about whether to stay home and age safely in place or to move out to a residential health care facility are referred to as “housing decisions” [9].

In Canada, housing decisions are considered the most frequent and difficult decisions for older adults receiving home care as well as for their caregivers [10,11]. The Ottawa Decision Framework identifies the factors influencing decisions as, in general, inadequate support and resources (or “decisional needs”) as well as personal characteristics such as gender, education, and ethnicity. In the context of housing decisions specifically, studies have shown that besides loss of autonomy, older adults in Canada consider moving for a variety of other reasons, such as caregivers’ opinions, proximity of services or relatives’ support, financial resources, and feelings of insecurity or fear at home [8,11]. One Canadian study showed that gender, age, household income, province, driving status, whether the current home met the older adults’ needs, and unmet heavy cleaning needs were all important influences on decisions to relocate [12].

Housing decisions and transitioning to long-term care can be experienced differently, depending on the sociocultural context. For instance, in Western cultures, some residential care facilities try to create a homelike atmosphere by allowing older adults to bring their furniture, pets, and family pictures to help ease the transition [13]. However, a meta-analysis showed that in the United States and Canada, older adults still experience transitioning to long-term care as a loss that requires a mourning process before coming to peace with the decision [14].

Amid the COVID-19 pandemic, housing decisions have become not only more frequent but also more painful and complicated for older Canadians [15]. The decision to relocate appears fraught with danger as long-term care homes and seniors’ residences were among the hardest-hit facilities in Canada in 2020 during COVID-19. Residents in nursing and senior homes accounted for >80% of all reported COVID-19 deaths [16].

To help older adults make informed decisions regarding the most appropriate housing option, shared decision-making (SDM) is advocated. SDM is the process of making a health care choice that involves patients, their relatives or family or both, and one or more health care professionals [17]. SDM is particularly appropriate for preference-sensitive decisions. The best housing decisions reflect older adults’ personal values and preferences, as well as those of their relatives [7,18]. As the need for self-management is increased by the cumulative effects of long-term conditions in older adults, SDM becomes more relevant, especially when it comes to housing. Besides, there is growing evidence that older adults and their caregivers would like to be more involved in decision-making [19]. Decision aids (DAs) can be used to facilitate SDM. DAs are evidence-based tools that support older adults in defining decisions, provide information regarding different options and outcomes, and help clarify personal values and priorities [20].

**eHealth** refers to health services and information delivered through the internet and related technologies [21]. According to recent studies, eHealth can empower older adults to manage their health by providing more accessible health information through educational and supportive web platforms and connection with others with shared health interests [22-25]. The use of eHealth has increased significantly since COVID-19. The accelerated digital transformation that has occurred [24] has encouraged older adults to use internet services to meet their needs in several aspects of life (eg, web-based groceries, web-based shopping, and health appointments). Because rapidly changing health conditions can quickly overtake older adults’ housing decisions [9], they need easily accessible web-based tools that can be updated to help them obtain the information they need to participate actively in SDM.

In a clinical setting, a DA is usually presented before the clinical encounter to prepare the patient for SDM with a health professional or during the encounter to prepare for a subsequent encounter. Few health professionals have the time to work through a DA with the patient and come to a conclusion on the
spot [26]. We designed an electronic version of a paper-based DA [27,28] (electronic decision aid [eDA]) to help older adults choose the most appropriate housing option for them. Older adults can use the eDA alone or with their families to prepare for SDM with a health professional. The eDA can also be used in SDM training for health care professionals to help them understand the practical steps involved in the SDM process. The paper-based DA is already available on the website of the Canada Research Chair in SDM and Knowledge Translation [28]. The eDA will also be made available free on this website. Brief details of the conversion are provided in Multimedia Appendix 1 [7]. We also plan to register it on the Ottawa Decision Aids website [20] and will suggest that partnering organizations provide hyperlinks to the eDA (eg, Fédération de l’Âge d’Or du Québec and L’Appui for caregivers).

Objective

We hypothesized that older adults would find the eDA to be useful. To our knowledge, no study has yet investigated whether older adults would be willing to use the eDA for housing decisions. Therefore, our aim was to assess Canadian older adults’ intention to use the eDA to make housing decisions and to identify the factors influencing their intention to use it.

Methods

Study Design

We conducted a cross-sectional web-based survey across Canada (including the 10 provinces and 3 territories) with older adults who had either made a housing decision in the past 12 months or were planning to make a housing decision the next year. We used the consensus-based Checklist for Reporting of Survey Studies (CROSS) to guide the reporting of our results [29] (Multimedia Appendix 2). This project is part of COORDINATEs (Technology to Support Decision Making About Aging at Home), an international study (Canada, Sweden, and the Netherlands), whose objective is to use technology to help older adults stay at home as long as possible in a safe manner and to assist them in making informed decisions about aging at home [9].

Ethics Approval

This project was approved by the Ethical Review Board of the Integrated University Health and Social Services Centre of the Capitale-Nationale, Québec, Canada (#MP-13-2019-1519, 2019-1519_SPPL).

Theoretical Framework to Guide the Survey Development

Health-related behaviors are correlated with intention, which is defined as an individual’s planned and rationalized decision to perform the behavior [30]. A meta-analysis of 10 meta-analyses showed that intention explained nearly one-third of the variance in behavior [31]. Using eHealth interventions to improve one’s health first requires acceptance of technology and then the intention to use it. Several theoretical models have studied the intention (and its determinants) to use technology in health care. The Unified Theory of Acceptance and Use of Technology (UTAUT) is among the most widely used theoretical models for studying the intention to use technology in health care [32]. Developed by Venkatesh et al [32], UTAUT is an extension of several theoretical models that preceded it, such as the Technology Acceptance Model [33] and Ajzen’s Theory of Planned Behavior [34]. UTAUT explains that behavioral intention to use technology is based on four constructs: (1) performance expectancy, defined as the degree to which individuals believe that using the system will help them gain advantages; (2) effort expectancy, defined as the degree of ease associated with the use of the system; (3) social influence, defined as the degree to which individuals perceive that their family, friends, and society in general would approve of them using the new system; and (4) facilitating conditions, defined as the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system [32]. To achieve the aim of this study, we adapted this framework by adding variables that could have a direct influence on the intention to use the eDA. Therefore, we measured sociodemographic variables as well as eHealth literacy, defined as “the use of emerging information and communication technology to improve or enable health and health care” [35]. eHealth literacy combines different dimensions of literacy skills (traditional literacy, health literacy, information literacy, scientific literacy, media literacy, and computer literacy; Figure 1) [36].
Respondents and Recruitment

Respondents were eligible if they were Canadian adults aged ≥65 years, understood English or French, had access to an electronic device with an internet connection, and had made a housing decision in the past few months or were planning to make one in the coming year.

We recruited respondents through Leger Marketing, a market research and analytics company in Montreal, Canada. Leger Marketing is the largest private Canadian web-based panel (400,000 individuals) and claims to be representative of the entire population [37]. It adopts a hybrid recruitment approach using traditional and mobile telephone methodologies through call centers, panel websites, and social media. It also updates panelists’ profiles every 6 months and controls the accuracy and quality of participants’ answers using validation techniques (eg, username and strict restrictions on passwords, deduplication with existing panel, and simultaneous recruitment campaigns) from the beginning of the registration process [37]. Leger Marketing selected our sample from its panel of 400,000 individuals using a nonprobability sampling method. An electronic invitation was sent to 11,972 older adults to complete the closed survey. The sampling methods used were representative of the general Canadian population in terms of age, gender, region, and socioeconomic status. Upon obtaining consent, eligible respondents were able to complete the survey. The survey was conducted on a voluntary basis and compensation was offered to respondents in the form of Leger Points, which are redeemable for cash or gift cards.

Each respondent from the web-based panel received a personalized email invitation containing a unique URL link to access the nonopen survey. Respondents were then asked to answer the first questions about language preference, province or territory of residence, and eligibility. Leger Marketing sent reminders via email once a week, until the survey was closed.

As respondents logged into the survey using their panel membership account, we had a unique response per member because it was not possible for the same member to have multiple submissions.

A minimum of 829 participants were required. The sample size was estimated using the central limit theorem formula [38]. This formula provides the recommended sample size to estimate the true population mean with the required margin of error and level of confidence. To determine the sample size, a similar study by Yousef et al [39] was chosen to estimate the SD of the mean intention score in the population (SD 0.56). The survey was closed once 1000 respondents had completed the survey. Recruitment took 4 weeks (April 5 to May 2, 2022).

Data Collection

Because no validated instruments that assess older adults’ intention to use an eDA for housing decisions have been identified, we created a self-administered questionnaire based on the adapted UTAUT items. We measured our main outcome, intention, and its 4 determining constructs using the 17 UTAUT-based items. Each UTAUT construct (intention, performance expectancy, effort expectancy, social influence, and facilitating conditions) was measured using 3 or 4 items. Respondents indicated their agreement or disagreement levels with the corresponding items on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). We calculated the final scores for each construct by averaging the scores of its corresponding items. In our UTAUT-based questionnaire, we replaced the word “technology” with “the web-based decision aid” and adapted the wording of each item to the context of our study. The UTAUT has good internal consistency and convergent and discriminant validity [32]. Cronbach α indicated good reliability of the multi-items measuring each construct (α range .9-.95).

Figure 1. Adapted version of Unified Theory of Acceptance and Use of Technology.
The survey also collected sociodemographic characteristics (ie, age, sex, gender, education, province or territory of residence, postal code, ethnicity, marital status, number of people in the household, mother tongue, and family income) using items based on Statistics Canada’s 2021 census questionnaire [40].

We evaluated eHealth literacy using 2 scales. The first was the Electronic Health Literacy Scale (eHeals) [41], a validated scale that measures respondents’ self-rated literacy level (referred to as “subjective scale”). eHeals was developed by Norman and Skinner [41] and is regarded as the “gold standard” for measuring eHealth literacy [41]. It is a validated 8-item scale with high internal consistency [42]. For each of the 8 items, respondents expressed their agreement or disagreement on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree), with higher scores reflecting better literacy skills. The eHeals scale generated a total score ranging from 8 to 40. On the basis of the different thresholds used in the literature to better classify literacy levels [43,44], eHealth literacy was considered high if the score was ≥26. We also used the Digital Health Literacy Instrument (DHLI) [45] to evaluate eHealth literacy. The DHLI (referred to as the “objective scale”) is a measure of the actual performance of respondents when using internet web pages. The DHLI subscale, originally Dutch, measures health-related internet use skills using 7 items [45]. The DHLI consists of screenshots of web pages with questions that assess operational skills, navigation skills, evaluation of reliability, determination of relevance, information searching, addition of self-generated content, and protection of privacy [45]. For this project, we adapted the DHLI to the Canadian context. After discussion with our research team members, only 5 items were included in the questionnaire. The 2 items concerning content addition and privacy protection were not directly related to this project and were omitted. If the respondent gave the correct answer, they received a score of 1. Otherwise, they obtained a score of 0. Therefore, the maximum possible score was 5. Cronbach’s αs for eHeals and DHLI were, respectively .91 and .35.

After completing the 2 eHealth literacy scales, the respondents were shown a 6-minute video vignette showing the use of the eDA in context. As mentioned by Godin et al [46], it is necessary to clearly define the targeted behavior (ie, use of the eDA for making housing decisions) before measuring the intention related to that behavior. The video was a demonstration of the SDM process regarding housing decisions and showed a situation where an autonomous older adult interacted with her caregiver who was concerned about her safety [47,48]. In the video, the older adult discussed the different housing options while using the eDA with her caregiver. All participants had to see the video to continue the survey and complete the UTAUT questions. The respondents were then asked to browse through the video to continue the survey and complete the UTAUT questions. The respondents were then asked to browse through the eDA [49]. Subsequently, UTAUT was used to evaluate respondents’ intention (and its related constructs of performance expectancy, effort expectancy, social influence, and facilitating conditions) to use the eDA [32]. On the basis of the eDA, the survey ended with questions about the process of making housing decisions using the following variables: chosen housing decision (“Which option did you choose or do you consider choosing?”), preferred housing options (“Which option do you prefer?”), reasons for considering housing options (“What are your reasons for making this decision?”), support in the decision-making process (“Who had helped you or can help you to make this decision?”), and preferred role in the decision-making process (“If you had to make this decision, how would you prefer the decision to be made?”). We treated these decision-making process variables as descriptive variables and did not include them in the multivariable analysis.

The survey was 48 web pages long, took approximately 30 minutes to complete, and consisted of 50 closed-ended questions that were not randomized and appeared in the same order for all respondents. Each page included a “next” button for moving forward and a button with a list of older adult helplines for talking to a specialist who could support them mentally or emotionally if they were uncomfortable with any of the survey questions. Respondents could not move to the next page unless they had completed all the questions on the current page. Surveys were labeled as complete only if respondents had clicked on the “finish” button located at the end of the survey. Both English and French versions were pretested with a sample of 76 respondents to identify any possible ambiguity or technical problems, validate the clarity of the questions, and estimate the average completion time. No major revisions were made following the pretest.

Data Analysis

We determined the distribution of our population for sociodemographic variables, levels of eHealth literacy, UTAUT constructs, and decision-making process variables using descriptive statistics (means, SDs, and percentages). Because intention scores could vary between 1 and 7, we interpreted intention as a continuous variable. There is no definitive threshold for a clinically significant intention score in the literature. We used the Shapiro-Wilk test to verify whether the distribution of the dependent variable was normal.

We considered the “prefer not to answer” choice as missing data (1.8%, 18/1000) for bivariate and multivariable analyses, except for the income variable. We calculated the age of the respondents by considering their date of birth and date of survey completion. We performed a mixed linear regression model including all the independent variables, that is, age, sex, gender, education, province or territory of residence, postal code, ethnicity, marital status, number of people in the household, mother tongue, family income, eHealth literacy (objective and subjective), performance expectancy, effort expectancy, social influence, and facilitating conditions, using stepwise selection with the Bayesian Information Criterion [50]. We used an alternative variable selection approach to validate our model. We conducted a bivariate analysis using simple linear regressions on each variable to describe the associations between the dependent variable (intention to use the eDA for housing decisions) and the independent variables. Variables with P values < .10 were considered significant, a threshold more stringent than the usual .20. We then included the selected independent variables in a multivariable analysis model and identified the factors associated with intention. We checked collinearity using a correlation matrix of the continuous variables (age, number of people in the household, eHealth literacy, performance expectancy, social influence, and
facilitating conditions; Multimedia Appendix 3). All analyses were performed using SAS (version 9.4; SAS Institute Inc) [51].

Results

Respondents’ Characteristics

Of the 11,972 panelists who were invited to participate, 3789 (31.65%) panelists clicked on the survey link received by email; 1176 (31.04%) met the eligibility criteria; and 1000 (85.03%) respondents completed the entire survey and were included in the analysis (Figure 2). The response rate was 31.65% (ratio of 3789 users who clicked on the survey link to 11,972 invitations sent), and the completion rate was 85.03% (ratio of 1000 users who completed the survey to 1176 eligible users who participated).

The included respondent’s characteristics are listed in Table 1. For the respondents who withdrew from the survey (14.97%, 176/1176), they had sociodemographic characteristics similar to those who fully completed the survey. Most respondents who withdrew were male (103/176, 58.5%) with a mean age of 73.9 (SD 6.0) years, White (160/176, 90.9%), living in Ontario or Quebec (101/176, 57.4%), and many were highly educated (64/176, 36.4% were university graduates). For the 1000 included respondents, the mean scores were 27.8 (SD 5.88) out of 40 for subjective eHealth literacy and 3.00 (SD 0.97) out of 5 for objective eHealth literacy. We consider that both scores represented high eHealth literacy levels. The subjective eHealth distribution was slightly skewed to the right in the direction of the highest score.

Figure 2. Flow of respondents.

- Potentially eligible panelists invited to participate (n=11,972)
- Panelists clicked on the survey link (n=3789)
- Eligible qualified panelists (n=1176)
- Eligible qualified panelists completed the full survey (n=1000)
- Panelists did not open the invitation email (n=8183)
- Panelists withdrew before qualification (n=537)
- Disqualified because of age (n=60)
- Disqualified because of nonconsent (n=102)
- Disqualified because they did not make the decision in the past months or did not intend to make the decision in the following year (n=1747)
- Disqualified because of their provenance from provinces for which we had achieved the required sample (n=138)
- Disqualified because of their nonsatisfactory responses (n=29)
- Panelists did not complete the full survey (n=176)
Table 1. Respondents’ characteristics (n=1000).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Respondents</th>
</tr>
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<tbody>
<tr>
<td>Age (years), mean (SD)</td>
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</tr>
<tr>
<td><strong>Sex, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>548 (54.8)</td>
</tr>
<tr>
<td>Female</td>
<td>452 (45.2)</td>
</tr>
<tr>
<td><strong>Gender, n (%)</strong></td>
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</tr>
<tr>
<td>Man</td>
<td>546 (54.6)</td>
</tr>
<tr>
<td>Woman</td>
<td>454 (45.4)</td>
</tr>
<tr>
<td><strong>Level of education, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>A university certificate, diploma, or degree</td>
<td>420 (42)</td>
</tr>
<tr>
<td>A college, CEGEP, or other nonuniversity certificate or diploma</td>
<td>264 (26.4)</td>
</tr>
<tr>
<td>A high school (secondary school) diploma or equivalent, a registered apprenticeship, or other trade certificate or diploma</td>
<td>286 (28.6)</td>
</tr>
<tr>
<td>Lower than a high school (secondary school) diploma or equivalent (eg, primary school)</td>
<td>25 (2.5)</td>
</tr>
<tr>
<td>I prefer not to answer</td>
<td>5 (0.5)</td>
</tr>
<tr>
<td><strong>Province or territory of residence, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Ontario</td>
<td>377 (37.7)</td>
</tr>
<tr>
<td>Quebec</td>
<td>251 (25.1)</td>
</tr>
<tr>
<td>Western Canada: British Columbia, Alberta, Saskatchewan, Manitoba, and Yukon</td>
<td>295 (29.5)</td>
</tr>
<tr>
<td>Eastern Canada: New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador</td>
<td>77 (7.7)</td>
</tr>
<tr>
<td><strong>Zone, based on postal code, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>850 (85)</td>
</tr>
<tr>
<td>Rural</td>
<td>141 (14.1)</td>
</tr>
<tr>
<td>I prefer not to answer</td>
<td>9 (0.9)</td>
</tr>
<tr>
<td><strong>Ethnicity, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>906 (90.6)</td>
</tr>
<tr>
<td>Non-White</td>
<td>73 (7.3)</td>
</tr>
<tr>
<td>Indigenous peoples of North America (First Nations, Métis, or Inuk [Inuit])</td>
<td>18 (1.8)</td>
</tr>
<tr>
<td>I prefer not to answer</td>
<td>3 (0.3)</td>
</tr>
<tr>
<td><strong>Marital status, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>Legally married (and not separated)</td>
<td>516 (51.6)</td>
</tr>
<tr>
<td>Divorced</td>
<td>152 (15.2)</td>
</tr>
<tr>
<td>Widowed</td>
<td>138 (13.8)</td>
</tr>
<tr>
<td>Never legally married</td>
<td>93 (9.3)</td>
</tr>
<tr>
<td>In a common-law union</td>
<td>81 (8.1)</td>
</tr>
<tr>
<td>Separated, but still legally married</td>
<td>19 (1.9)</td>
</tr>
<tr>
<td>I prefer not to answer</td>
<td>1 (0.1)</td>
</tr>
<tr>
<td><strong>Number of people in the household, mean (SD)</strong></td>
<td>1.80 (0.81)</td>
</tr>
<tr>
<td><strong>Mother tongue, n (%)</strong></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>629 (62.9)</td>
</tr>
<tr>
<td>French</td>
<td>283 (28.3)</td>
</tr>
<tr>
<td>Other(^b)</td>
<td>88 (8.8)</td>
</tr>
<tr>
<td>Aboriginal languages(^c)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>
Family income, n (%)                              

<table>
<thead>
<tr>
<th>Income Range</th>
<th>Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD $100,000 (US $76.923) or more</td>
<td>172 (17.2)</td>
</tr>
<tr>
<td>CAD $75,000-$99,999 (US $57.700-US $76.922)</td>
<td>153 (15.3)</td>
</tr>
<tr>
<td>CAD $50,000-$74,999 (US $38.461-US $57.692)</td>
<td>221 (22.1)</td>
</tr>
<tr>
<td>CAD $25,000-$49,999 (US $19.230-US $38.460)</td>
<td>262 (26.2)</td>
</tr>
<tr>
<td>&lt;CAD $25,000 (US $19.230)</td>
<td>114 (11.4)</td>
</tr>
<tr>
<td>I prefer not to answer</td>
<td>78 (7.8)</td>
</tr>
</tbody>
</table>

eHealth literacy (subjective)\(d\), mean (SD)   
27.8 (5.88)

eHealth literacy (objective)\(e\), mean (SD)  
3.00 (0.97)

\(a\) CEGEP: Collège d'enseignement général et professionnel.
\(b\) Other: Spanish, Mandarin, Arab, Cantonese, Dutch, Flemish, German, Greek, Gujarati, Hindi, Hungarian, Igbo, Indo, Italian, Lithuanian, Polish, Portuguese, Punjabi, Romanian, Russian, Serbian, Slovak, Slovenian, Tamil, Ukrainian, and Urdu.
\(c\) Aboriginal languages in Canada: Algonquian languages (eg, Cree, Ojibway, Innu or Montagnais, and Mi’kmaq), Inuit languages, Athabaskan languages, Salish languages, Siouan languages, Iroquoian languages, Tsimshian languages, Wakashan languages, Michif, Haida, Tlingit, and Kutenai.
\(d\) Sum of 8 items on a 1 to 5 Likert scale (1=strongly disagree and 5=strongly agree). Scores range from 8 to 40.
\(e\) Sum of 5 items (score 0 if wrong answer, score 1 if correct answer). Scores range from 0 to 5.

**Intention and UTAUT Construct Scores**

The UTAUT construct scores are shown in Table 2. The mean score of older adults’ intention to use the eDA to decide about housing was 4.74 (SD 1.7) out of 7. We considered intention scores of ≥4 sufficient to assume that older adults would use eDA for housing decisions. As for the other UTAUT constructs, facilitating conditions had the highest mean score of 5.63 (SD 1.28) out of 7. Older adults seemed to believe that organizational and technical infrastructure existed to support the use of the eDA. The mean scores of performance expectancy, effort expectancy, and social influence were, respectively, 4.94 (SD 1.48), 5.61 (SD 1.35) and 4.76 (SD 1.59), that is, older adults believed that the eDA would help them to make better decisions and found it easy to use, and the eDA was approved by their relatives, so they would be more inclined to use it.

Cronbach \(\alpha\) values are presented for each assessed construct and are a measure of internal consistency for each construct. This is considered to be a measure of scale reliability.

The intention scores associated with each decision-making process variable are listed in Table 3.

**Table 2. Unified Theory of Acceptance and Use of Technology (UTAUT) construct scores (n=1000).**

<table>
<thead>
<tr>
<th>UTAUT construct(a)</th>
<th>Scores, mean (SD)</th>
<th>Cronbach (\alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intention</td>
<td>4.74 (1.70)</td>
<td>.95</td>
</tr>
<tr>
<td>Performance expectancy</td>
<td>4.94 (1.48)</td>
<td>.94</td>
</tr>
<tr>
<td>Effort expectancy</td>
<td>5.61 (1.35)</td>
<td>.95</td>
</tr>
<tr>
<td>Social influence</td>
<td>4.76 (1.59)</td>
<td>.95</td>
</tr>
<tr>
<td>Facilitating conditions</td>
<td>5.63 (1.28)</td>
<td>.90</td>
</tr>
</tbody>
</table>

\(a\) Averaging the scores of the corresponding items on a Likert scale from 1 to 7. The scores range from 1 to 7.
Table 3. Intention scores associated with decision-making process variables (n=1000).

<table>
<thead>
<tr>
<th>Chosen housing option</th>
<th>Respondents, n (%)</th>
<th>Intention scores, mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Only 1 chosen option</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stay in your home</td>
<td>736 (73.6)</td>
<td>4.64 (1.7)</td>
</tr>
<tr>
<td>Move to a family member’s home</td>
<td>17 (1.6)</td>
<td>4.29 (1.8)</td>
</tr>
<tr>
<td>Move to a private seniors’ residence</td>
<td>78 (7.8)</td>
<td>5.25 (1.5)</td>
</tr>
<tr>
<td>Move to a public residential or long-term care center</td>
<td>16 (1.6)</td>
<td>5.37 (1.7)</td>
</tr>
<tr>
<td><strong>2 chosen options</strong></td>
<td>88 (8.8)</td>
<td>4.87 (1.7)</td>
</tr>
<tr>
<td><strong>3 chosen options</strong></td>
<td>14 (1.4)</td>
<td>5.30 (1.6)</td>
</tr>
<tr>
<td><strong>4 chosen options</strong></td>
<td>2 (0.2)</td>
<td>6.00 (0.0)</td>
</tr>
<tr>
<td>Other option, specify</td>
<td>49 (4.9)</td>
<td>4.8 (2.0)</td>
</tr>
<tr>
<td><strong>Preferred housing option</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stay in your home</td>
<td>843 (84.3)</td>
<td>4.67 (1.7)</td>
</tr>
<tr>
<td>Move to a family member’s home</td>
<td>25 (2.5)</td>
<td>4.79 (1.6)</td>
</tr>
<tr>
<td>Move to a private seniors’ residence</td>
<td>75 (7.5)</td>
<td>5.2 (1.6)</td>
</tr>
<tr>
<td>Move to a public residential or long-term care center</td>
<td>17 (1.7)</td>
<td>5.43 (1.8)</td>
</tr>
<tr>
<td>Other option, specify</td>
<td>40 (4)</td>
<td>4.9 (1.9)</td>
</tr>
<tr>
<td><strong>Reasons for considering housing options</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Only one reason</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Someone else thinks you should move</td>
<td>26 (2.6)</td>
<td>4.93 (1.7)</td>
</tr>
<tr>
<td>You are concerned about your health</td>
<td>149 (14.9)</td>
<td>5.11 (1.5)</td>
</tr>
<tr>
<td>You are less able to walk or move around</td>
<td>44 (4.4)</td>
<td>3.95 (1.4)</td>
</tr>
<tr>
<td>You do not feel safe</td>
<td>8 (0.8)</td>
<td>5.08 (1.8)</td>
</tr>
<tr>
<td>You do not have enough help at home</td>
<td>21 (2.1)</td>
<td>5.23 (1.7)</td>
</tr>
<tr>
<td>You feel lonely</td>
<td>31 (3.1)</td>
<td>4.83 (1.6)</td>
</tr>
<tr>
<td>You have trouble doing your groceries, getting to the pharmacy, getting to the physician’s office, etc</td>
<td>28 (2.8)</td>
<td>4.87 (1.5)</td>
</tr>
<tr>
<td>Your relatives can no longer give you the support you need</td>
<td>22 (2.2)</td>
<td>5.0 (1.8)</td>
</tr>
<tr>
<td><strong>More than 1 reason</strong></td>
<td>253 (25.3)</td>
<td>5.05 (1.6)</td>
</tr>
<tr>
<td>Other option, specify</td>
<td>418 (41.8)</td>
<td>4.42 (1.8)</td>
</tr>
<tr>
<td><strong>Support in the decision-making process</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spouse</td>
<td>271 (27.1)</td>
<td>4.44 (1.8)</td>
</tr>
<tr>
<td>Children</td>
<td>181 (18.1)</td>
<td>4.83 (1.6)</td>
</tr>
<tr>
<td>Grandchildren</td>
<td>5 (0.5)</td>
<td>4.13 (2.3)</td>
</tr>
<tr>
<td>Other family member</td>
<td>53 (5.3)</td>
<td>4.83 (1.6)</td>
</tr>
<tr>
<td>Friends</td>
<td>46 (4.6)</td>
<td>4.63 (1.6)</td>
</tr>
<tr>
<td>Physician</td>
<td>26 (2.6)</td>
<td>4.14 (1.7)</td>
</tr>
<tr>
<td>Social worker</td>
<td>11 (1.1)</td>
<td>4.82 (2.2)</td>
</tr>
<tr>
<td>Family and friends only</td>
<td>211 (21.1)</td>
<td>4.9 (1.6)</td>
</tr>
<tr>
<td>Health care team only</td>
<td>10 (1)</td>
<td>6.0 (0.9)</td>
</tr>
<tr>
<td>Both (family, friends, and health care team)</td>
<td>186 (18.6)</td>
<td>5.02 (1.6)</td>
</tr>
</tbody>
</table>

Preferred role in the decision-making process
Factors Associated With Intention

Table 4 shows factors significantly associated with intention in the multivariable model. In order of importance, these factors were performance expectancy ($\beta=.55; P<.001$), social influence ($\beta=.37; P<.001$), mother tongue ($\beta=.30; P<.001$), facilitating conditions ($\beta=.15; P<.001$), and eHealth literacy (objective) ($\beta=-0.06; P=.03$). On the basis of these results, we proposed a modified parsimonious UTAUT model (Figure 3). Overall, our final model explained 73.3% of the total variance of our dependent variable.

The alternative variable selection approach (ie, the selection of independent variables in the bivariate analyses using the threshold of 0.1 before conducting the multivariable analysis) resulted in the same final model. In total, 9 variables were retained in the bivariate analyses (Multimedia Appendix 4).

Table 4. Multivariable factors significantly associated with older adults’ intention to use the electronic decision aid.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Respondents, n (%)</th>
<th>$\beta$ (95% CI)$^a$</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother tongue</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English (ref)$^b$</td>
<td>629 (62.9)</td>
<td>N/A$^c$</td>
<td>N/A</td>
</tr>
<tr>
<td>French</td>
<td>283 (28.3)</td>
<td>.30 (0.17 to 0.43)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Other</td>
<td>88 (8.8)</td>
<td>.06 (−0.11 to 0.28)</td>
<td>.57</td>
</tr>
<tr>
<td>eHealth literacy (objective)</td>
<td>1000 (100)</td>
<td>−0.06 (−0.1 to −0.005)</td>
<td>.03</td>
</tr>
<tr>
<td>Performance expectancy</td>
<td>1000 (100)</td>
<td>.55 (0.49 to 0.61)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Social influence</td>
<td>1000 (100)</td>
<td>.37 (0.32 to 0.43)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Facilitating conditions</td>
<td>1000 (100)</td>
<td>.15 (0.10 to 0.21)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

$^a$The estimated $\beta$ for each variable and its 95% CI are presented in the table.

$^b$Ref: reference category for the analysis.

$^c$N/A: not applicable.

Figure 3. The final proposed model.
Discussion

Principal Findings

To the best of our knowledge, this is the first web-based survey across the 10 Canadian provinces and 3 territories to investigate older adults’ intention to use an eDA for housing decisions. The mean intention score was moderate. In addition, we found that older adults’ most chosen and preferred housing option was to stay in their homes. Most participants had multiple reasons for this preference, which were largely related to their health conditions. Older adults were mostly supported by spouses or children in making their housing decisions, and the majority preferred to play an active role in the decision-making. We also found that intention varied across Canada according to the respondents’ mother tongue. French native speakers were more likely to use the eDA for housing decisions than those with other mother tongues. In addition, objectively evaluated eHealth literacy was negatively associated with intention (ie, a lower level of eHealth literacy was associated with higher intention scores), whereas subjectively evaluated eHealth literacy was not. Finally, the UTAUT constructs of performance expectancy, social influence, and facilitating conditions were significantly and positively associated with intention. In other words, respondents with higher scores for performance expectancy, social influence, and facilitating conditions had a greater intention to use the eDA for housing decisions. These results allowed us to make the observations elaborated in the following sections.

Interpretation and Comparison With Prior Work

First, scores representing older adults’ intention to use the eDA in this study were positive and similar to the scores in 3 studies using UTAUT model in the context of digital health care, which ranged from 2.8 to 4.42 [39,52,53]. The first study was a systematic review investigating the acceptance of web-based interventions for addressing various physical and mental health conditions among patients and health professionals [53]. The second study examined patients’ intentions to use their eHealth records [39], and the third study examined older adults’ intentions to use eHealth applications [52]. It is difficult to predict whether the intention score in our study is sufficient for older adults to adopt the targeted behavior (to use the eDA). As mentioned, there has been no definitive initiative to determine a cutoff point for clinically significant intention scores. All things considered, because there was no ceiling effect with regard to the intention score [54], suitable strategies and interventions should still be developed considering the factors influencing intention identified in our study to prompt older adults to use the eDA and thus make better informed housing decisions.

Second, our results suggest that older adults who are supported in their decision-making process by their family, friends, and health care team are more inclined to use the eDA to make housing decisions. Other studies have confirmed the importance of relatives in the decision-making process regarding housing options [10,11]. Therefore, it could be useful to add a section in the eDA to be filled in by caregivers who are involved in the decision. Comparing older adults’ and caregivers’ preferences could allow for a better understanding of each point of view and their respective needs, values, and priorities. This would better prepare older adults and their families for SDM discussions with each other and with their health professionals (eg, doctors, social workers, physiotherapists, and occupational therapists) and reduce the decisional regrets of older adults [11] and caregivers [10]. The eDA could thus be a useful tool in the implementation of an interprofessional SDM model, which stresses the importance of facilitating communication between different parties involved in the SDM process to reach common ground about the issues at stake, especially when it comes to sensitive topics such as housing decisions [55,56].

Third, contrary to our expectations, of the 11 sociodemographic variables in the study, only the mother tongue remained in the final model. Our results suggest that francophone Canadians are more inclined to use the eDA than anglophones. This might be because the province of Quebec, where most Canadian French native speakers live, has the highest percentage of older adults living in residential care in the country [57]. In 2021, 17% of Quebecers were aged ≥75 years and lived in senior residences, compared with only 5%-10% in the other provinces [57]. In addition to this cultural choice, Quebec dedicates a large share of its home care resources to tax credits, 83% of which are used to pay rent for older adults’ private long-term care residences, instead of funding public services (eg, personal support workers) to enable people to stay in their homes [58]. Owing to these budgetary choices, the proportion of older people with access to publicly funded home care services has fallen sharply over the last years. Owing to such pressures and the growing rate of older adults, housing decisions are becoming more complex than ever before in Quebec; therefore, Quebecers would see more need for a tool that supports them in their housing decisions.

Quebec is considered as a “distinct society” whose culture and social values are different from those in English Canada [59,60]. A higher willingness to use the eDA in Quebec could also be attributed to the fact that the eDA was developed by a francophone research team affiliated with Université Laval, Quebec. Although the eDA was translated into English, it was originally designed in French, and the designers of the eDA may have unintentionally reflected Quebecers’ interests and values more than those of other Canadian populations. In addition, a web-based survey assessing Canadians’ health-related decision-making processes showed that being an older adult living in the province of Quebec decreased the level of SDM experienced [61]. This could explain why Quebecers are more eager to engage in SDM and use the eDA when presented with the possibility of doing so.

Fourth, even though eHealth literacy, whether measured objectively or subjectively, was associated with intention in the bivariate analysis, only the objective measure of eHealth literacy remained in the multivariable model and seemed to have had a stronger influence on intention. This result confirms the importance of measuring eHealth literacy both objectively and subjectively. Believing oneself to have high literacy levels is not sufficient and needs to be completed with objective performance measurements, which count more in terms of assessing behavioral intentions related to health [62]. Contrary
to our hypothesis, we found a negative correlation between objective eHealth literacy and older adults’ intention to use the eDA for housing decisions. The eDA was designed as a simple tool. As most respondents in our sample had high eHealth literacy scores, they might have expected a more sophisticated tool. This could explain their lower intention to use the eDA. Another possible explanation is that because eHealth literacy positively correlates with health literacy [36,63], respondents might have expected an eDA richer in content and information. Conversely, respondents with lower eHealth literacy scores were more inclined to use the eDA. This could be explained by the simplicity of the eDA. It is important to pay attention to those who have limited skills in using digital technologies. A study of low-income American older adults in 2020 showing that only half of the participants used the internet and of these, less than half had high eHealth literacy scores [44]. Older people are disproportionately affected by the “digital divide” [64]. Future research on eDAs could focus on the relationships among content, design, health literacy, objective eHealth literacy levels, and older adults’ intention to use them.

Fifth, as expected, we found that the 3 UTAUT constructs (performance expectancy, social influence, and facilitating conditions) were significantly associated with intention. In other words, the more respondents believed that the eDA would improve the quality of their decision-making, that their social circle would approve of the use of the eDA, and that they had the necessary assistance for using web-based resources, the more they intended to use the eDA to decide about housing. Only the construct effort expectancy was excluded from the final model. Our results are congruent with those of other studies related to eHealth, except for effort expectancy, which was included in their models and not in ours [65,66]. As explained by Venkatesh et al [32], if the targeted behavior has not been experienced before by older adults (ie, the use of the eDA) and if effort expectancy is not present in the model, then facilitating conditions are expected to become the main predictor of intention. This was the case in this exploratory study. Moreover, Venkatesh et al [32] stated that according to the various models on which his theory is based, performance expectancy is the strongest predictor of intention of all the constructs, which was confirmed in our study. In contrast with our findings, de Veer et al [52] excluded social influence from their final model, although they found that family and friends influenced the intention to use eHealth. This might be because we operationalized social influence differently; de Veer et al [52] used only 1 item to measure social influence, whereas we used 3. Nonetheless, we too observed that respondents with higher-than-average intention scores benefited from social support (ie, family, friends, and health care team) in their decision-making process (Table 3).

Finally, our findings suggest that UTAUT constructs and behavior change methods [67] could be used to design strategies focusing on facilitating conditions and social influence that would enhance older adults’ intention to use the eDA. For example, health and social care workers could be mobilized to promote the use of the eDA across different health care settings, in residential care facilities or when providing homecare services [67]. As also suggested by Bartholomew et al [67], mobilizing persuasive communication strategies and social networks could be helpful when disseminating the eDA. Members of social networks (eg, family members and relatives, caregivers, peers, and health care professionals) could help inexperienced older adults use eHealth resources [67,68].

**Strengths and Limitations**

The strength of our study was that this was a rigorous theory-based analysis of the intentions of older adults across Canada, a country that stretches 4700 miles coast to coast, to better support them in making one of their most difficult decisions. Furthermore, Leger Marketing, the survey firm, balanced our recruited sample across age, sex, gender, and socioeconomic status. In addition, the response rate in our study (3789/11,972, 31.65%) was higher than the average for web surveys, which usually ranges from 10% to 20% [69–71], and higher than the average response rate for the Leger panel.

Our study has a few limitations. First, our sample cannot be considered representative of all Canadian older adults because we excluded those with no internet access and most of our respondents were White, English speaking, highly educated, and male. Respondents may have been in a more privileged position than the average Canadian in terms of decisions about housing, that is, they could hire private home care workers or pay for private residential care [72]. A selection bias may have occurred because people with higher eHealth literacy are more likely to subscribe to private panels such as this one [70,73]. Rhodes et al [74] point out the pitfalls of collecting data electronically without considering the “digital divide,” or with the inaccurate assumption that web access and use is equal among subgroups within a country’s population. Second, in the Leger panel the percentage of respondents from the Canadian territories was lower than the percentage from the provinces, whereas the percentage of Indigenous people is higher in the territories (eg, 86% in Nunavut) than in the provinces. Thus, it is possible that Indigenous people were not adequately represented in our sample. Compounding this limitation, only 43.3% of households in the First Nations reserves have access to high-speed internet [75]. Third, our sample was limited to older adults who had made the decision to move in the past few months or were planning to make this decision in the coming year. This criterion was somewhat restrictive, as, according to Leger Marketing, some respondents from the territories screened out at this point in the survey. Fourth, we were able to measure older adults’ intention to use eDA, but we cannot say that they will definitely use it. Studies that ask follow-up questions after a lapse of a few months can address this limitation. Finally, this study was conducted during the COVID-19 pandemic period. Although the pandemic affected housing decisions in older adults living in residential care [76], we did not include specific questions related to the pandemic; thus, our survey did not take this into account.

**Conclusions**

Our study is the first to assess Canadian older adults’ intention to use an eDA to help them make housing decisions. This study makes both empirical and conceptual contributions to the field of eHealth behavior. We were able to provide a better understanding of the relationships between intention and its
constructs and examine the effects of various variables on intention. In addition, we propose a modified parsimonious theoretical framework based on UTAUT, involving additional relevant concepts such as eHealth literacy. Research on older adults’ decision-making about housing (e.g., eDA development, assessment of intention to use it, and eventually its implementation and integration into various care trajectories) has become increasingly relevant. This study is a step forward toward facilitating eDA implementation and integration initiatives. Our findings and conclusions can be applied in similar sociodemographic contexts where older people are an increasingly large proportion of the population and need support to play an active decision-making role throughout their care continuum.

Acknowledgments
We acknowledge Louisa Blair for her precious work and kind editorial help with the manuscript. We also thank Sergio Cortez Ghio for his support with statistical analysis.

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Data Availability
The data sets used and analyzed during this study are available from the corresponding author upon reasonable request.

Authors’ Contributions
MF, KVP, VB, and FL contributed to study design. MF was responsible for data collection. MF, SG, AG, KVP, VB, and FL analyzed the data. MF, VB, AG, and FL contributed to manuscript writing. All authors were responsible for manuscript revision.

Conflicts of Interest
FL holds the Canada Research Chair in Shared Decision Making and Knowledge Translation.

Multimedia Appendix 1
Details of the conversion of the paper-based decision aid to electronic decision aid.
[DOCX File, 13 KB - aging_v611e43106_app1.docx]

Multimedia Appendix 2
Consensus-Based Checklist for Reporting of Survey Studies.
[DOCX File, 21 KB - aging_v611e43106_app2.docx]

Multimedia Appendix 3
Correlation matrix of the continuous variables (age, number of people in the household, eHealth literacy, performance expectancy, social influence, and facilitating conditions).
[DOCX File, 17 KB - aging_v611e43106_app3.docx]

Multimedia Appendix 4
Factors associated with older adults’ intention to use the electronic decision aid in bivariate analyses.
[DOCX File, 19 KB - aging_v611e43106_app4.docx]

References
2. In the midst of high job vacancies and historically low unemployment, Canada faces record retirements from an aging labour force: number of seniors aged 65 and older grows six times faster than children 0-14. Statistics Canada. 2022 Apr 27. URL: https://www150.statcan.gc.ca/n1/daily-quotidien/220427/dq220427a-eng.htm [accessed 2022-09-04]


20. Patient Decision Aids. The Ottawa Hospital Research Institute. URL: https://decisionaid.ohri.ca/ [accessed 2022-05-06]


28. Brière N, Emond J, Garvelink M, Légaré F, Stacey D. To get the care and services I need, should I stay in my home or move? Canada Research Chair in Shared Decision Making and Knowledge Translation. URL: https://drive.google.com/file/d/12c0D7_nILE5zn-tir3YKiOaXT4J9pC11/view. [accessed 2022-12-23]
40. Recensement de la population. Statistics Canada. URL: https://www23.statcan.gc.ca/imdb/p2SV[page number not for citation purposes]

49. Brière N, Emond J, Garvelink M, Légaré F, Stacey D. To get the care and services you need, should you stay in your home or move? Qualitrics. URL: https://chairedpac.yul.qualtrics.com/jfe/preview/previewld/04bf0f3c-0df4-4a7d-9e88-532fdbb4b53c/SV_1Wylhp1Za5mHyq/Q_CHL=preview&Q_SurveyVersionID=current [accessed 2022-04-05]


68. Airola E. Learning and use of eHealth among older adults living at home in rural and nonrural settings: systematic review. J Med Internet Res 2021 Dec 02;23(12):e23804 [FREE Full text] [doi: 10.2196/23804] [Medline: 34860664]

Abbreviations

CROSS: Checklist for Reporting of Survey Studies
DA: decision aid
DHLI: Digital Health Literacy Instrument
eDA: electronic decision aid
eHeals: Electronic Health Literacy Scale
SDM: shared decision-making
UTAUT: Unified Theory of Acceptance and Use of Technology
Understanding Older Adults’ Experiences With Technologies for Health Self-management: Interview Study

Elsy Paola Garcia Reyes¹, MA, MBA, BSc; Ryan Kelly¹, BSc, MSc, PhD; George Buchanan¹, BSc, PhD; Jenny Waycott¹, BA, PhD

School of Computing and Information Systems, Faculty of Engineering and Information Technology, The University of Melbourne, Melbourne, Australia

Corresponding Author:
Elsy Paola Garcia Reyes, MA, MBA, BSc
School of Computing and Information Systems
Faculty of Engineering and Information Technology
The University of Melbourne
Parkville Victoria
Melbourne, 3010
Australia
Phone: 61 3 9035 5511
Email: egarciareyes@student.unimelb.edu.au

Abstract

Background: Many older adults now use technologies such as wearable devices and telehealth services to support their health and well-being while living independently at home. However, older adults vary in how they use these technologies, and there is a lack of knowledge regarding the motivations that influence their acceptance and use of health-related technologies in home environments.

Objective: This study aimed to understand the types of technologies that older adults use to support their health and the factors that motivate them to use their chosen technologies to support their health. In addition, we aimed to understand the factors that enable the effective use of technologies for health self-management and to identify the barriers that can negatively affect the adoption of technologies.

Methods: A total of 22 older adults participated in semistructured interviews regarding their experiences of using technologies for health self-management. Interview transcripts were analyzed through an in-depth thematic analysis.

Results: The interviews revealed that a range of technologies, such as videoconferencing software, fitness trackers, and other devices, were being used by older adults to support their health. Interviews showed that participants were motivated to use technologies to monitor health issues, to stay active and connected, and to record and change their behavior in the light of foreseen risks related to their future health status. Enablers that facilitated the effective use of technologies include social and organizational influence, convenient access to health care and safety provided by the technology, and easy setup and low cost of the technology. Barriers include information overload and a sense of futility about future health decline; telehealth being an inadequate substitute for in-person consultation; concerns about trust related to privacy and accuracy; and technologies being stigmatizing, uncomfortable to use, expensive, and unfamiliar.

Conclusions: This study suggested that older adults were using a variety of technologies to prevent or prepare for future health decline, evidencing a resilient attitude toward health and aging. In addition, older adults were willing to continue using the technology when there was a perceived need. The enabler mentioned by most participants was the social and organizational influence that included health care staff, family, friends, and organizations. This analysis provides a better understanding of how older adults use technologies to support their health and can guide the provision of appropriate health technologies for them.

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KEYWORDS
older adults; technology; health self-management; motivator; enabler; barrier
Introduction

Background

Information and communication technologies have considerable potential to support older adults in accessing health care services and in self-managing their health. Recently, the COVID-19 pandemic has accelerated the interest in supporting older adults’ health and has emphasized the critical importance of self-monitoring as a facet of public health [1]. Self-management refers to an individual’s ability to manage symptoms; treatments; lifestyle adjustments; and the psychosocial, cultural, and spiritual consequences of health conditions, specifically chronic diseases, in collaboration with family, community, and health care professionals [2]. Examples of technologies for health self-management include wearable devices, telecare, sensor-based monitoring systems, and mobile apps. These technologies can help older adults to control their diet and physical activity or achieve emotional self-control [3-5]. Such technologies, if used effectively, could increase the efficiency of health care, reduce the workload for providers, reduce medical costs, and improve older adults’ well-being [6]. Furthermore, these technologies can enable older adults to maintain their autonomy and independence as they age [7-9].

Recent research related to technology adoption among older adults has indicated that older adults are increasingly familiar with digital technologies [10-12] and are interested in using technology to manage their health, such as measuring heart rate, keeping an activity diary, and monitoring stressful situations [13,14]. However, older adults’ experiences with technology can vary greatly, and many factors can influence whether an older adult successfully uses technologies for health self-management. This means that there is reason to be cautious about predicting the rising uptake of health technology by older adults. Previous quantitative studies have shown that older adults have reservations about using health-related technologies to obtain health information and advice [15,16]. However, these studies were conducted between 3 and 6 years ago, and the situation could have changed in recent years, as these technologies have become more commonplace.

Other studies suggest that there are a range of factors that affect the adoption of health technologies by older adults. Researchers have investigated older adults’ use of activity trackers and sleep monitoring devices [13,14,17-20]. Although there is a positive interest in using such technologies, encouraging their ongoing use is a challenge [19], and social support has been identified as the main motivation for encouraging the use of these technologies in long-term users [14]. In addition, studies have concluded that the design and use of wearable devices and mobile apps must consider age-related cognitive, sensory, and motor function changes in the older generation to ensure the adoption of these technologies by them [13,20].

We also understand some of the potential applications of this technology. A key principle is supporting aging in place, where older adults are supported in living independently in their established home and community, rather than moving to specialist accommodation [21]. Previous studies have identified possible barriers to technology adoption for aging in place.

These barriers include device usability, accessibility, reliability, affordability, and privacy [22,23]. Concerns about trust related to privacy and security, stigma, the lack of control over technology, the lack of human response, inaccuracy, need for training, and anxiety are further impediments [24,25]. A comprehensive review of smart residential environments added that security, the lack of interoperability, complexity, and the lack of perceived utility were concerns of older adults [7]. Almathami et al [26] conducted a systematic review of the factors that influence the use of web-based home health consultation systems or telemedicine health services. They identified internal factors, including users’ behaviors and motivations while using and interacting with the system and patients’ beliefs and perceptions of the relative advantages and disadvantages of the web-based home health consultation system.

The role of assistive technology in supporting the health of older adults has also received attention. Greenhalgh et al [27] conducted a study with 40 participants to develop a theoretical model of assistive technology use. They found that telehealth and telecare seldom met older adults’ needs and did not assist them to live with an illness. Yusif et al [28] conducted a systematic review of factors that concern older adults in their decision to adopt assistive technology. They identified privacy as the main concern to older adults, followed by trust, the lack of functionality or added value, financial cost, and the ease of use. Other factors that negatively affect technology adoption included the suitability for daily use, perception of no need, stigma, fear of dependence, and lack of training.

These studies have collectively focused on why older adults have hesitated to or have been prevented from using technologies before or after they are familiar with them. However, the studies did not examine the motivations of older adults for using these technologies. This study closes this gap. It takes a broad perspective, looking at a variety of technologies that participants identify as relevant to their health self-management. This perspective provides a vital understanding of older adults’ needs and, consequently, can improve the use of technologies and care for older adults.

Objectives

This study aimed to understand the technologies that older adults use to support their health and the factors that motivate them to use technologies to support their health. In addition, this study aimed to understand the factors that enable the effective use of technologies for health self-management and to identify the barriers that can negatively affect technology adoption. We adopted a qualitative approach involving semistructured interviews with 22 participants.

Understanding the motivators, enablers, and barriers that affect technology-based health management is essential to ensuring that future technologies are designed and deployed appropriately. To be effective, technologies must be designed to align with health self-management at a time of life when good health is not guaranteed.
Methods

Ethics Approval
All procedures were approved by the Human Research Ethics Committee of The University of Melbourne (ID# 1955800).

Participants and Recruitment
We recruited participants by contacting organizations that provide services to older adults who live independently at home. The recruitment criteria included individuals who were aged >65 years; lived in Melbourne (Australia); used a device for their health care (e.g., home blood pressure monitor, blood glucose monitor, fitness tracker, etc); and spoke English.

A total of 5 organizations distributed information about our research to their members. Respondents who registered their interest in the study were then contacted, and an interview was arranged. A total of 22 participants agreed to be interviewed. Drawing on the concept of “information power,” this sample size was deemed sufficient [29]. Using information power as a guiding principle to assess the appropriate sample size in qualitative research gives weight to criteria such as clearly defined aims, sample specificity (e.g., older adults who use technologies for health self-management), and the quality of conversations with interviewees. Our study met these criteria; therefore, we are confident that a sample size of 22 is sufficient to gain in-depth insights into the phenomenon studied. Furthermore, this sample size is in line with guidelines based on a meta-analysis of typical sample sizes required to reach theoretical “saturation” in qualitative data [30], and the study found that saturation is typically reached with between 8 and 17 interviews.

All the interviews were conducted from October 2020 to January 2021. To protect their anonymity, all the participants have been given a pseudonym and are referred to by their pseudonym in the Results section.

Procedure
Participation was voluntary, and the participants did not receive compensation in the study. Participants read a plain language statement and signed a consent form. All interviews were conducted by author EGR. The interviews were held via phone or videoconference, using WhatsApp (Meta Platforms Inc), FaceTime (Apple Inc), or Zoom (Zoom Video Communications), from October 2020 to January 2021. We conducted interviews to gain an in-depth understanding of older adults’ motivations and experiences that affect their acceptance and use of technologies for health self-management. The interviewer asked questions related to the acquisition and use of technologies that participants used to manage their health, questions about participants’ motivations for using these technologies, who influenced participants’ decisions to use these technologies, and what they did not like about these technologies.

Data Analysis
Each interview was audio recorded following the participant’s approval. Then, the interviews were transcribed verbatim and analyzed using thematic analysis [31]. The thematic analysis involved the following six stages: (1) becoming familiar with the data, (2) generating codes, (3) generating initial themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. The data were coded by EGR using an inductive approach. Preliminary codes, subthemes, and key themes were refined through discussions among the research team. NVivo (version 12; QSR International) software was used to identify and categorize the codes and organize the data.

Results

Participants
A total of 22 people agreed to be interviewed, including 14 (64%) women and 8 (36%) men. Participants’ age ranged from 65 to 87 (mean 73, SD 6) years. Most participants (n=20, 91%) were educated beyond secondary school. A total of 14 (64%) participants were living with their partner, and 8 (36%) participants were living alone. Additional demographics are summarized in Table 1. Multimedia Appendix 1 provides more details about the interviewees.
Table 1. Participant demographics (N=22).

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>73 (6)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>14 (64)</td>
</tr>
<tr>
<td>Male</td>
<td>8 (36)</td>
</tr>
<tr>
<td>Highest level of education, n (%)</td>
<td></td>
</tr>
<tr>
<td>Tertiary institution, university, or other higher educational institution</td>
<td>20 (91)</td>
</tr>
<tr>
<td>Secondary school</td>
<td>2 (9)</td>
</tr>
<tr>
<td>Marital status, n (%)</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>13 (59)</td>
</tr>
<tr>
<td>Widowed</td>
<td>4 (18)</td>
</tr>
<tr>
<td>Single</td>
<td>3 (14)</td>
</tr>
<tr>
<td>Divorced</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Employment, n (%)</td>
<td></td>
</tr>
<tr>
<td>Retired</td>
<td>19 (86)</td>
</tr>
<tr>
<td>Semiretired</td>
<td>2 (9)</td>
</tr>
<tr>
<td>Working part time</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Household composition, n (%)</td>
<td></td>
</tr>
<tr>
<td>Live with his or her partner</td>
<td>14 (64)</td>
</tr>
<tr>
<td>Live alone</td>
<td>8 (36)</td>
</tr>
<tr>
<td>Need for help or supervision, n (%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>17 (77)</td>
</tr>
<tr>
<td>Yes, sometimes</td>
<td>5 (23)</td>
</tr>
<tr>
<td>Reasons for help or supervision, n (%)</td>
<td></td>
</tr>
<tr>
<td>No need for help or supervision</td>
<td>17 (77)</td>
</tr>
<tr>
<td>Long-term health condition</td>
<td>3 (14)</td>
</tr>
<tr>
<td>Short-term health condition</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Other cause or community services come in to clean</td>
<td>1 (5)</td>
</tr>
</tbody>
</table>

Types of Technologies Used

Participants mentioned a range of technologies they used to support their health activities at home. These included videoconferencing software and phone devices to access health care services (telehealth), wearable devices to monitor activity and health status, personal alarm systems to alert carers in the case of emergencies, web-based sources for health information, and a range of other specific health technologies.

Telehealth, a remote health care service, was the technology used by most respondents (14/22, 64%). To access telehealth, the participants used videoconferencing software or phone calls.

Among the wearable devices mentioned by the 22 respondents were fitness trackers (n=8, 36%) and personal alarm systems such as pendant alarms (n=6, 27%). In addition, the participants mentioned using medical devices such as blood pressure monitors (n=9, 41%), blood sugar or glucose monitors (n=4, 18%), hearing aids (n=5, 23%), a pulse oximeter that measures blood oxygen level and pulse rate (n=1, 5%), a continuous positive airway pressure (CPAP) machine that treats sleep apnea disorders (n=1, 5%), an implantable cardiac defibrillator and pacemaker (n=1, 5%), and a pelvic floor stimulator that strengthens the pelvic floor muscles to reduce incontinence (n=1, 5%).

Some participants identified mobile devices (n=4, 18%) and personal computers or laptops (n=3, 14%) as technologies they used to look after their health. Moreover, 6 (27%) participants were using apps related to food and physical activities.

All the participants (22/22, 100%) had access to the internet, and 5 (23%) of them commented that they used the internet to search websites for information related to their health. Other technologies mentioned by the participants included Google Calendar, used by 1 (5%) respondent as a diary to...
remember medical appointments and activities, and a customized spreadsheet, used by another participant (n=1, 5%) for health monitoring and tracking. A summary of these technologies is presented in Table 2.

Table 2. Types of technologies used to support participants' health activities at home (N=22).

<table>
<thead>
<tr>
<th>Types of technologies</th>
<th>Participants, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Remote health care service</strong></td>
<td></td>
</tr>
<tr>
<td>Telehealth</td>
<td>14 (64)</td>
</tr>
<tr>
<td><strong>Wearable devices</strong></td>
<td></td>
</tr>
<tr>
<td>Fitness tracker</td>
<td>8 (36)</td>
</tr>
<tr>
<td>Personal alarm system</td>
<td>6 (27)</td>
</tr>
<tr>
<td><strong>Medical devices</strong></td>
<td></td>
</tr>
<tr>
<td>Blood pressure monitor</td>
<td>9 (41)</td>
</tr>
<tr>
<td>Hearing aids</td>
<td>5 (23)</td>
</tr>
<tr>
<td>Blood sugar or glucose monitor</td>
<td>4 (18)</td>
</tr>
<tr>
<td>Pulse oximeter</td>
<td>1 (5)</td>
</tr>
<tr>
<td>CPAP&lt;sup&gt;a&lt;/sup&gt; machine</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Implantable cardiac defibrillator and pacemaker</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Pelvic floor stimulator</td>
<td>1 (5)</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
</tr>
<tr>
<td>Apps related to food and physical activities</td>
<td>6 (27)</td>
</tr>
<tr>
<td>Mobile device</td>
<td>4 (18)</td>
</tr>
<tr>
<td>Personal computer or laptop</td>
<td>3 (14)</td>
</tr>
<tr>
<td>Google Calendar</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Customized spreadsheet</td>
<td>1 (5)</td>
</tr>
</tbody>
</table>

<sup>a</sup>CPAP: continuous positive airway pressure.

**Motivators: Factors That Motivate the Use of Technologies for Health Self-management**

**Overview**

We present 3 themes that provide insight into why participants were using technology to manage their health. First, many participants were motivated by the need to keep track of health-related information to manage chronic health conditions, such as diabetes, and to stay independent. Second, participants were motivated to use technology to stay active and socially connected and saw this as an important part of their health self-management. Third, some participants were motivated to use technologies to monitor their health and change their behavior because of prior knowledge and awareness of personal risks related to their future health decline.

**Theme 1: Monitoring Chronic Health Issues to Stay Independent**

Of the 22 participants, 14 (64%) said that their main motivation for using technology was to monitor their health issues. Within this group, 12 (86%) participants reported that the technology was useful for monitoring or helping manage existing medical conditions or disabilities. For example, 1 (7%) participant used an app to track vital signs and blood pressure that could affect his health and to be in contact with his physician (general practitioner):

> I have an app on my phone that is connected to my GP and so my cholesterol levels, my heart rate, my weight, blood pressure, are all communicated back to him. If I enter a value in here, it shows up on his screen and if he’s concerned he will text me to come and see him or just...It will text me to make an appointment. In fact, I got one earlier this week where he said, it’s time for your skin check. So, I get the skin check. I’ll take that phone off. [P2, Bob]

Furthermore, 3 (21%) participants commented that if they did not monitor their health issues, they would lose their capabilities and risk losing their independence, as described by Nancy:

> I think I’m going to end up with knee surgery, probably a knee replacement. I’ve had minor knee surgery because I also tore a cartilage doing some stuff, but I think I’m going to end up with a knee replacement. Health, I’m going to have to keep control of diabetes because I know otherwise my independence, if I would lose my vision or if my kidneys start failing, that’s going to really affect again my independence. So, I’ve got a handle on the diabetes so that the...That just gets harder as the
system gets older so I really, really got to work on that. [P14, Nancy]

In addition, 3 (21%) participants wanted to be healthy to avoid being a burden to their family. A participant commented the following:

Some people would say money is more important. Some people would say family is more important, but I figure, no matter how healthy you are, if your health is rotten, money means nothing. And if put family first and your healthy is no good, you are a burden on your family and they look after you. So you have to be healthy so you can do what your family might need regardless of your age. [P11, Katy]

Participants reported that technologies such as telehealth and wearable and medical devices were useful for monitoring or assisting with medical conditions or disabilities. These findings suggest that these health technologies fulfill the purpose for which they are designed and help older adults maintain their independence by monitoring and managing their health.

**Theme 2: Staying Active and Connected**

Most of the participants performed technology-supported activities that helped them stay physically or mentally active and connected with family and friends. Overall, 14 (64%) of the 22 participants used technologies that were aligned to their objectives to stay active. For example, one participant commented as follows:

I have a Fitbit, which I carry in a pocket all the time. I aim for 10,000 steps, but don’t often get there since I had the problem with the disk [back injury]. But I’m usually over 2000 or thereabouts. Sometimes higher. I do tend to sit. We also have weighing scales that are connected to the Fitbit. So I keep track of my weight, and also the percent body fat. And I think that’s it. [P13, Michael]

Of the 22 participants, 5 (23%) who were using apps related to fitness and food, videoconferencing software, and hearing aids mentioned that they shared information related to the progress and goals of their activities with relatives and friends. This helped them to stay socially connected:

The Strava app is a really good app because it links you with a group of friends, people you know who are also doing something similar so if you can’t meet in person, you can sort of meet with your chat on the Strava app after you’ve recorded a ride. And, people give you positive comments, or they talk about the photos, or they say, well done for the distance or gee, that was a lot of mountain climbing you did today. So, you get a lot of positive feedback from your friends so I think that’s a very positive thing. [P7, Gwen]

One participant who had a hearing impairment and was using hearing aids to go out, talk to people, or watch television mentioned that hearing aids helped her avoid isolation:

Yes. I’d say that they’re very important. The hearing aids are especially important, otherwise you’re isolated from people and can’t understand what they’re saying… [P3, Cyndi]

Of the 22 participants, 3 (14%) reported that these technologies helped them perform regular activities. One participant used a Google Calendar to plan his daily activities:

And I have diary that is on Google. I find that very useful to plan my appointments and things like that. Doctors’ appointments, that sort of thing. And to make sure that I don’t forget things that I need to do. I think that’s pretty important. [P6, Frank]

**Theme 3: Knowledge of Risk of Future Health Decline**

Of the 22 participants, 10 (45%) demonstrated an awareness of risk to certain diseases, especially because of known genetic traits in the family. On the basis of this knowledge, participants tried to prevent or monitor diseases they suspected were more likely to develop. One participant spoke about how his family history of stroke meant he had increased motivation to monitor his blood pressure, leading him to adopt a blood pressure monitor:

Well, currently, I’m undergoing no major medical treatment so that will be the first thing. I do take blood pressure medication and that type of thing, so my blood pressure is actually controlled, fortunately. Obviously that may have contributed to my father’s, maybe even my grandfather’s stroke. So it’s been very important for me to keep my blood pressure under control. So that means taking the proper medication and getting it reviewed regularly. [P6, Frank]

Within this group, 2 (20%) out of 10 participants reported familiarity with health self-management technologies because their close relatives used them to monitor their own medical conditions. For example, one participant commented as follows:

Well, I guess, my late wife had high blood pressure, and she had the monitor to keep a check on that, and so I’d use it [blood pressure monitor] occasionally, just more or less for a bit of fun and see what the readings were. [P10, John]

In addition, 3 (30%) participants believed that they had a duty to know about their own health. A participant was motivated to use blood pressure and blood glucose monitors so that she could control her health:

Sometimes people get frightened because they think of bad news. I’ve heard of people who won’t get tested for diabetes in case they have to stop eating cake. I think, would you rather be blind? So, yes, personally I like to know. The things I can control I would rather control, so I’d rather have the knowledge. That’s important except, as I said, there’s only so many things that you can twitch about. [P14, Nancy]

**Enablers: Factors that Enable the Use of Technologies for Health Self-management**

Our analysis revealed 3 factors that enable the positive uptake of technologies for health self-management. These include social and organizational influence, convenient access to health care...
and safety provided by the technology, and easy setup and low cost of the technology.

**Theme 4: Social and Organizational Influence on Decisions to Use Technology**

Social and organizational influence was identified as an enabler in the use of technologies for health self-management. All 22 (100%) participants mentioned that health care staff, family, friends, or organizations influenced their use of technologies.

### Health Care Staff

Of the 22 participants, 11 (50%) mentioned that health care staff recommended or suggested using technologies for health self-management to prevent, monitor, and treat health issues. The participants could monitor their health and report the readings from the device to the medical staff if the results were not within the normal range. A participant described several different technologies recommended by the medical staff:

> Well, that [related to the CPAP machine] was a specialist recommendation. But I guess I use it differently to how some people might use it. I extract the card and I read the data on it and check the progress. I don’t bother going back to the sleep physician. I’ve actually got training treatment of sleep disorders, so I know what the data means and if something’s not looking right, then I’ve got a reasonably good idea about what I need to do about it. So that was that was specialist advice. Hearing aids, I’ve had a hearing impairment since childhood. But I only was aided once I was about 40. So again, that was kind of consultation with a health professional that says this could be helpful for you. Blood pressure monitor again,...I suppose, it’s medical advice which says this would be a good idea, or I recommend this or something like that. Yeah. [P15, Olivia]

### Family and Friends

Overall, 3 (14%) participants reported that supportive family members helped them use the technologies. The family members made it easier for older adults to use technologies. A participant said that she received help from her family to use the blood pressure monitor:

> My husband has to get it [blood pressure machine] out of the cupboard for me. He usually helps me put it on my arm. I can do that myself, but it’s just easier if he does it, and he knows how to line it up or that sort of stuff. One of my daughters is a registered nurse and she lives not far from me. There have been times when I haven’t been feeling good and she’s come to my house. She can do those readings easily. It’s generally family members who use the machines, but I will do it myself as long as I can get access to it, even if it’s tucked away in a drawer or something, I can usually get it out when I need to. [P17, Rita]

Furthermore, 3 (14%) participants received technologies as gifts from their families, and 5 (23%) participants acquired the technologies because their family or friends were using them.

A participant started to use an app because her husband was using it:

> Because he was already on Strava and I could see how much enjoyment he was getting out of it, and so after a little while I decided to join as well and I enjoy it so much that I probably do more recording than he does. [P7, Gwen]

Another participant was influenced by her friends to obtain a fitness tracker because they used fitness trackers to monitor their activities:

> I guess the Fitbit, friends had them. And I thought, ‘Oh, that sounds like a good idea, to monitor your activity.’ And it does give you encouragement. And I don’t participate in groups, this is just me looking at what I do. [P12, Linda]

### Organizations

In addition, 5 (23%) participants were using technologies such as apps related to food, blood glucose monitors, hearing aids, or a pendant alarm based on information received from organizations. These were nonprofit organizations that cater to people aged >50 years and public and private organizations that provide assistance with conditions such as diabetes, tinnitus, hearing loss, or dementia. In some cases, these organizations allowed their clients to trial their technologies before purchasing them:

> Well, with Academic Hearing, I went there, and they asked me if I’d trial their hearing aids, and I trialled them, and they said yes I could have them. [P19, Tina]

Moreover, 7 (32%) participants had the cost of the devices subsidized by the government, care organizations, or health insurance companies. A participant said the following:

> There’s an organisation in Australia, Diabetes Australia and a lot of things are subsidised if you were a diabetic or if you have a record, medical diagnosis or diabetes. So, the test strips are heavily subsidised and that’s where the companies make their big money so they’re very, very interested in giving you the monitor so you would the test strips. Because if you bought them independently, I think they are 50, 60, maybe $70 a packet. And I get them for $5 something, $6 but they’re getting 50, $60 a box of tests. So, they want you to use their things. [P14, Nancy]

Furthermore, 8 (36%) participants received help or technical support for the technologies from government or technology providers. One participant stated the following:

> Well, the hearing aids are the ones that the government provides for pensioners, so there’s no financial support except I pay for batteries and having them checked up. Once a year I go for a checkup with them. The pendant is...What’s it called? Well they do come, supposed to come once a year and check them, and once a month I ring the alarm just to see that it’s working. [P3, Cyndi]
In addition, 2 (9%) participants mentioned that their living arrangements provided support for their needs that enabled independent living. That is, they saw the value of technologies for supporting independent living. One lived in a retirement village and the other in public housing (affordable government-owned homes that support older adults with accommodation issues). Both participants moved into homes that offered support and immediate assistance through technologies for health self-management. One participant who had a chronic illness and disability and lived in public housing said the following:

"I love my little home and this chair and my computer and easy cooking and all of those things...And they did an upgrade of the units two and a half years ago, and they absolutely focused on my disability needs...I've got an oxygen concentrator here, I've got P2.5 masks and everything has been done to enable my functioning...all those fine details which the number of faxes and emails for my doctors to get everything that we reckoned, this was a one-off change to get this unit right for my aging, more assistive technologies [scooter, walking stick, pickup stick, orthopaedic lift up chair, and push along walker]." [P22, Zoe]

Another participant moved to a retirement village because of her husband's health issues and the need to access support:

"The pendant alarm is part of being in the village, and that was one of the reasons we moved here, to have that sort of backup after my husband's brain tumor. We didn’t know what the future meant for him, so that's been handy because he was recently ill, and pressed the pendant, and the ambulance was here straight away." [P19, Tina]

**Theme 5: Technology Provided Convenient Access to Health Care and Safety**

In total, 13 (59%) out of the 22 respondents commented that technology such as telehealth was convenient and enabled prompt medical attention. The technology provided efficiency benefits because it reduced travel and wait times at hospitals for the participants:

"It wasn't really very much available before, but I will continue to use it now, because there’s no point driving out to the doctor if you don’t need to see him. It takes less time for the doctor to see you on telehealth and less of your time as well." [P1, Amy]

Furthermore, 3 (14%) participants who needed support mentioned that older adults who could not move easily or needed to stay home could benefit from telehealth because of its convenience and easy access to medical staff. As one participant noted, telehealth improved access to health services:

"Telehealth, I think telehealth for some people is really good, and at times for old people because sometimes you just can’t get somewhere. So being able to have sort of a consult with a doctor but not a situation where it’s five minutes or 10 minutes and you’re in and out, but a proper consult with your own doctor can be great at those times when people are housebound where they can’t move easily and can’t get out." [P8, Helen]

Overall, 8 (36%) participants, including 3 (38%) of the 8 who were living alone and needed support, said that they used technologies such as pendant alarms because they offered safety and access to services and support. This enabled the participants to feel comfortable living independently:

"The pendant because I live alone and I do a few risky things like climbing ladders, so in case I have a fall I’ve got someone I could contact. Otherwise, I’d be on my own without help." [P3, Cyndi]

**Theme 6: Easy Setup and Low Cost of the Technology**

In addition, of the 22 participants, 7 (32%) commented that the technologies that they were using to monitor their health were easy to set up and use. A participant who was using apps related to fitness said the following:

"No, there’s nothing I don’t like about it [related to the app]. I found it easy to use. No, there’s nothing I don’t like about it. It serves its purpose for me so I like it." [P7, Gwen]

Of the 22 participants, for 4 (18%) of them, cost was not an issue to obtain and use technology. A participant commented that the price to buy technologies for health self-management such as blood pressure monitor, pendant alarm, pulse oximeter, and telehealth was affordable:

"I haven’t sought financial support, because they’ve all been within a reasonable price bracket." [P17, Rita]

**Barriers and Challenges: Factors that Discourage the Use of Technologies for Health Self-management**

**Overview**

Our analysis identified 4 barriers and challenges that interviewees had encountered when using technologies for monitoring their health. Barriers include information overload and a sense of futility about future health decline; telehealth being an inadequate substitute for in-person consultation; concerns about trust related to privacy and accuracy; and technologies being stigmatizing, uncomfortable to use, expensive, and unfamiliar.

**Theme 7: Information Overload and Sense of Futility About Future Health Decline**

Of the 22 participants, 10 (45%) were motivated to manage their health because of the risk of developing certain conditions. There were 2 (9%) participants, however, who appeared to feel overwhelmed by gaining too much knowledge about their existing conditions from using the technologies. This caused them distress and anxiety. For example, a participant who was using devices such as a blood pressure monitor, blood glucose monitor, and a fitness tracker to control diabetes said the following:

"You’re a diabetic whose weight has got high glucose level but weight now follows your need to exercise more, but you’ve got this pain. So what can we do..."
first? Are there any signs that we need to change to diet? And what are you prepared to do? But it just gets more difficult the more things you have to think about.

So I think people go for the easy stuff and I’m just trying to think, “All right. Try not to think about the cardiovascular stuff. I didn’t need to know that. I really did not need to know that.” The arthritis and the diabetes is enough, thank you and COVID made me very anxious, so I was very anxious. [P14, Nancy]

Another participant, who had hyperacusis and was unable to tolerate loud sounds, commented that she received news about possible complications owing to the use of hearing aids and she had to decide whether she would be deaf or experience the complications of using hearing aids. This information caused her more distress because she had already been dealing with other health issues:

Well what are normal sounds for most people, cars going along the street and so on, or a dog barking. She [neurologist] said, ‘I’ve had to set your hearing lower than I’d like because of all of that.’ But the sound was too much. So we’re in the trial stage and you know I might have to make the choice, okay I’m just going to get deaf and I might make the choice that I’m going to struggle with this. But I’m going to get brain symptoms if I use them [related to hearing aids]. My eyes are tearing up as I say all of that. It’s very hard. [P22, Zoe]

Of the 22 participants, 5 (23%) expressed a sense of futility about future health decline stating that no matter what they did, they could not avoid inherited or other diseases. One participant who used a blood pressure monitor and a fitness tracker said that she was concerned that she would still have cardiovascular disease, as her family members had had before her:

Well, unfortunately my genetic background is full of heart trouble. So I presume I will end up with heart problems. Other than that, there has been cancer in the family, but not immediate family. So hopefully there would no problem there. And someone said as we get older, the worry is that you fall over and that could be a problem as well. [P21, Whitney]

The participants commented that no matter what they did to be healthy, as they got older, they would become more fragile and more prone to disease, and something unexpected could happen:

And as you get older you’re going to expect to get more frail, and you’ll probably get cancer or something at some time, but that’s life. Who knows what’s going to front up, but when you get to 75, you’ve got max 25 years left, so you’re going to pop off sometime. [P10, John]

**Theme 8: Telehealth Cannot Fully Replace In-Person Consultations**

Some participants commented on the limitations of telehealth. In total, 4 (18%) participants communicated with physicians through phone calls, whereas others (5/22, 23%) communicated by Zoom. However, patients had to visit the hospital when physical examination or immediate attention was necessary. A participant who had osteoarthritis and mild sleep apnea and had consulted with the physician over the phone commented the following:

So, in the last nine months I would say, I’ve used a combination of...sometimes I’ve had to go to the doctor’s in person for an injection right? You can’t do that with Telehealth. But other times I’ve been able to have a consultation over the phone. [P18, Sarah]

In addition, the participants mentioned that there was the lack of interaction and connection with the medical staff. The participants had used telehealth through their phones, and they could not interact with the physician. Therefore, they preferred face-to-face interactions:

But with telehealth, I understand that it’s necessary to do because you can’t have personal contact, but for me, if you can’t have a personal dialog with your medical practitioner, it’s not quite the same thing. I don’t think...if you don’t have that connection with the eyes that you understand exactly what they mean, because sometimes a doctor can say to you, ‘That’s really what I need you to do, do you understand?’ And sometimes you do, but sometimes they may mean...something a little bit more dramatic that the very serious...So look, in the telehealth that I’ve been doing, it’s been by phone...So there’s been no visual...So that’s been unsatisfactory. But I like the doctor and so I’ve still tried to do the best you can. [P9, Isaac]

**Theme 9: Concerns About Trust Related to Privacy and Accuracy**

Security and privacy implications were mentioned by 4 (18%) of the 22 participants. The participants were concerned about privacy related to providing data for data collection, sharing information, and avoiding identity theft from technologies such as fitness trackers, apps, videoconferencing software, and messaging apps:

I guess the privacy concerns are just the suggestions are that the old people were worried about rumors and suggestions of people intruding on identity theft of getting knowledge about you in certain ways. And also of course, I imagine you understand the words, scams, the sort of…that sort of thing, yes. [P16, Paul]

I don’t join my Fbit up to the…anything else. I refuse to give away my analog information. I don’t know where it’s going, so I don’t have it joined up to the app. I’ve turned the app off so that it just gives me numbers and I charge. [P14, Nancy]

In addition, 3 (14%) participants reported the inaccuracy of the measurement of the blood pressure monitor:

I am, just because of my physics background, suspicious of their accuracy, which as I said, I had three [related to blood pressure monitor], and I’ve taken measurements from using all three in quick
succession, or simultaneously, and then cross checked the results, so I always have a degree of skepticism about their precision. [P10, John]

Theme 10: Health Care Technologies Can Be Stigmatizing, Uncomfortable to Use, Expensive, and Not Familiar

Of the 22 participants, 2 (9%) participants expressed concerns about the visibility of the device and the stigma associated with using health care devices such as pendant alarms. The participants believed that they were wearing a technology that targeted older adults with frailty. By using these technologies, other people could perceive them as frail or with poor health condition. For example, one participant commented as follows:

I remember my late mum she used to have to wear something around her neck which she hated 24/7 and felt like a cow. She really hated that and I can totally relate now. So we were talking about devices that might help us, like something that we could wear on our wrist perhaps the Apple Watch for example or some other device that was on our wrist that was not intrusive and didn’t look awful and identify us as being in a certain age group and having certain health problems and all of those types of things. So something like that definitely we would both look into it. [P8, Helen]

Furthermore, 4 (18%) participants reported discomfort when using health-related technologies such as CPAP machine, blood pressure monitor, hearing aids, and implantable cardiac defibrillator. A participant who had sleep apnea mentioned that she felt uncomfortable while using it:

...And I mean, with things like C-PAP machine, no one in their right mind would get one if they didn’t need one, because it’s hideously, intrusive and uncomfortable. It’s awful to have to use. So if I had a choice I wouldn’t use it ever. [P15, Olivia]

In addition, 1 (5%) participant expressed concerns about the cost of technologies:

So, for example, with a C-PAP machine, cause I’ve used one for about 10 years, I think and I’m on my second machine. They have a lifespan of about five, six years maybe. They’re expensive. They’re very expensive in Australia. If I lived in the US I’d get one for a third of the price, even from a company that’s designed it in Australia. So really pisses me off that for some things where you really have little choice, you’re not supported through Medicare [Australian public health insurance system], but you need these things and yet you’re talking thousands of dollars. So if they need a service, that can be a thousand dollars. So I suppose like with any technology I suppose the thing that frustrates me with them is sometimes the need for maintenance is high and there’s a cost associated with that. [P15, Olivia]

Furthermore, 2 (9%) participants expressed an issue regarding the battery of the devices that drained quickly. A participant mentioned the following:

The costs of charging. You seem to always...have you got it charged, or haven’t you got it charged, and that’s probably the most annoying thing. And if you go anywhere, you seem to take more chargers than anything with you. [P19, Tina]

In addition, 3 (14%) participants also shared concerns about their lack of familiarity with the technology:

The only thing I would say is, although most older people are quite tech savvy now, there’s still a lot of people who don’t have a computer. So there’s still that gap...

So, for example, I’m president of a group and there’s about 15 people in it. And several of them I have to communicate with them either by going in person or by writing to them snail mail. Or by ringing them up because that’s what I can do with them.

And with others, I can quickly either send a text because lots of people got phones, but not everybody knows how to text. [P18, Sarah]

Discussion

Principal Findings

This study aimed to understand what types of technologies older adults use to support their health, what motivates older adults to use technologies to support their health, and what factors enable the effective use of technologies for health self-management. Finally, this study investigated the barriers that negatively affect the adoption and use of technologies for health self-management.

A range of communication technologies such as videoconferencing software or phone calls were most commonly used to enable telehealth consultations. Wearable devices, medical devices, and web-based sources for health information were also discussed. Motivators that encouraged participants to use technology included a desire to monitor their health, stay active and connected, and monitor health signs, especially when they were already aware of a personal risk related to future health decline. Enablers that facilitated the positive uptake of technologies for health self-management included social and organizational influence, technology-enabled convenient access to health care and safety, and easy setup and low cost of the technology.

However, our findings showed that there are challenges that affect the use of technology by older adults. These include feeling overwhelmed by too much information; feelings of helplessness about future health decline; telehealth being a poor substitute for in-person consultation; concerns about trust in system privacy and accuracy; and technologies being stigmatizing, uncomfortable to use, expensive, and unfamiliar.

In the following sections, we discuss the importance of our findings in relation to previous work and present further interpretations.
Motivators to Use Technology: Planning for Resilient Aging

We found 3 main motivators for using technologies for health management among our participants. Drawing on these findings, we argue that the knowledge of future adversities provided a sense of power and control for some of our participants. They expressed attitudes toward aging that demonstrated personal resilience and used technologies for health self-management to prevent or prepare for future health decline.

These findings can be interpreted using the lens of resilient aging. Resilience is defined as the ability to recover from difficult situations, that is, “an extraordinary atypical personal ability to revert or ‘bounce back’ to a point of equilibrium despite significant adversity” [32]. Adversity can be viewed in terms of living conditions that lead to personal losses, inequalities, disabilities, and general challenges of aging [33].

Researchers have identified the ways in which systems can be designed for future resilience. Our findings suggest that participants have different approaches to preparing for future resilient aging. This points to a type of resilience that is related to the definition provided by Woods [34]: “to be resilient, a system looks ahead to read the signs that its adaptive capacity as it currently is configured and performs is becoming inadequate to meet the demands it will or could encounter in the future.” According to Hollnagel [35], the fundamental functions for resilience include anticipating and monitoring changes and threats, being proactive, ensuring the ability to respond to interruptions, and learning from past experiences.

We observed this pattern of resilience in some of our participants. Knowledge of future adversities provided them with a sense of power and control, and knowledge about what to expect in the future meant that they knew what to do about their health and could make decisions with this knowledge in mind. For example, some participants, who monitored their health because of their family history, took early action and planned ahead to avoid or delay the appearance of hereditary diseases. Dismissing information about their health and not doing something about it could make them more susceptible to health decline and the loss of independence. A previous study reported that risk factors for the loss of independence in later life include poor mental and physical health, social isolation, the loss of mobility, inappropriate environment and living conditions, and the lack of resources [36]. Thus, older adults are likely to benefit from using technologies that allow them to maintain their independence; give them control and authority over the characteristics and functions of the technologies; and do not make them appear weak, dependent, or in need of special care [37].

In contrast, other participants showed less resilience. For these participants, this knowledge could cause anxiety and stress, as this information overwhelmed them and they did not know what to do. That is, information about the deterioration of their health created a feeling of helplessness in some participants. Previous research found that information overload creates stress, fatigue, burnout, and even interruption in the use of information sources [38,39]. In addition, information overload negatively affects psychological well-being and influences the intention to discontinue the pursuit of health information [39] and results in information avoidance [38].

We argue that participants who chose technology to track health and activity information were those who expressed a resilient attitude by preparing in advance to prevent or delay the onset of hereditary diseases. In contrast, those participants who said they felt overwhelmed with the information provided about their existing medical conditions were using technology to manage their health. This leads us to argue that the link between resilience and technology use for health self-management warrants further investigation.

Enablers to Use Technology: Social and Organizational Influence Is the Most Mentioned

This study identified 3 enablers in using technologies for health management among our participants.

First, our findings showed that social and organizational influence positively affected technology use. All the participants mentioned the influence of family and friends, healthcare staff, and organizations. In this study, social and organizational influence provided information about health-related technologies and helped in motivating the use of these technologies. In addition, some technologies were subsidized, and older adults received help or technical support from nonprofit organizations related to older adults; public and private organizations that research and assist people with diabetes, tinnitus, hearing loss, and dementia; or technology providers. Social and organizational influence became enablers and positively affected the use of technologies when they helped overcome technology barriers. In contrast to the Technology Acceptance Model [40] and the Unifying Theory of the Acceptance and Use of Technology [41], we observed clear evidence that social and organizational factors not only influenced the intention to use technologies but also shaped how they were used in practice. The influence of social context on actual use is not found in either model, so capturing this would be a vital element in a framework that captures the use of supportive technologies by older adults.

Previous research showed that older adults who received support in addressing technological challenges were more willing to use various products and devices in their daily lives [42]. Family members, friends, and medical staff often comment and recommend recent technology to older adults, and this influences older adults’ technology use decisions [42]. According to Tseng et al [43], the opinions of other older adults can influence older adults’ acceptance of the health monitoring system. On the basis of this finding, influential people such as health care professionals, family, and caregivers could be included in the design of the technologies for health self-management because they are familiar with the technology owing to the assistance they provide to older adults.

In addition, we found that organizational influence such as supported living arrangements influenced the participants’ decisions about using technology. These accommodations offered support and prompt assistance to the participants through technologies for health self-management. Consistent with these findings, previous research has found that older adults at risk of losing their independence will try to adjust to their...
environment, such as finding suitable housing that will allow them to carry out the daily activities necessary to maintain their independence [36].

Focusing on the second enabler, we observed that our participants found technology such as telehealth to be convenient, enabling them prompt access to medical attention. In addition, participants who needed assistance mentioned that older adults who could not move around quickly or needed to stay at home might benefit from telehealth owing to its convenience and easy access to medical staff. In addition, the technology demonstrated efficiency benefits because it reduced travel and wait times at hospitals for the participants. Furthermore, participants who lived alone and required assistance mentioned using technologies such as pendant alarms because they provided safety and access to services and support. This finding supports the evidence from a previous study in which participants mentioned the benefits of telehealth, including convenience and cost [26]. In addition, participants reported that telemedicine health services were convenient because they eliminated travel and waiting times, saved money, and allowed them to complete the consultation from the comfort of their homes at any time [44]. In addition, results related to the safety provided by the technology are consistent with the studies in which participants reported a sense of safety and security because of using technologies, as well as a desire to use technologies to prevent or detect accidents and medical emergencies [45,46].

Finally, participants stated that the technologies that they were using to monitor their health were simple to set up and use and affordable. In a systematic review of web-based home consultation platforms, Almathami et al [26] found that the ease of use related to the ease of navigation and use of services and savings, based on the cost of mileage traveled per patient.

In this study, the enabler that was the most mentioned by the participants was the social and organizational influence. All the participants mentioned the influence of family and friends, health care staff, or organizations in their use of technologies. Therefore, we can conclude that social and organizational influence can play an important role in determining whether and how older adults will use health care technologies.

Perceived Need Trumps Barriers and Challenges

We found that our participants faced similar barriers to technology adoption as reported in previous studies related to using home health care technology such as wearable devices, smart home technologies, telemedicine, and other technologies that help older adults remain at home [24,47-56].

One of the barriers is that some participants felt overwhelmed by the information provided by the technologies related to their existing health conditions. This information overload caused anguish and anxiety. This finding broadly supports studies related to mobile health services and glucose monitoring, and they state that information and system feature overload increased older adults’ fatigue and stress, thereby increasing their resistance to the adoption of these technologies [57,58].

One finding concerns the limitations of telehealth, such as the lack of physical examination or immediate attention and lack of interaction and connection with the medical staff. This finding accords with that of previous studies, in which participants expressed an interest in connecting with their health care provider for the want of human interaction [59] and a perceived lack of care integrity when care was delivered through video visits [60].

Our findings also highlighted older adults’ concerns about trust related to privacy and accuracy. These results corroborate the findings of the previous work of LaMonica et al [61], who observed that data privacy and security risks were primary barriers to health technology use. If the digital technology is provided by reputable sources such as health organizations, universities and academics, and individuals with higher degrees or qualifications, these barriers could be mitigated. In addition, some studies related to monitoring systems or electronic health records have revealed that older adults have concerns about the privacy and confidentiality of their health information [49,50,62]. This is challenging to overcome, as the purpose of these systems is to collect and share their data, and these concerns could influence their willingness to adopt and use them.

In addition, some studies showed that older adults with greater concern for privacy will choose human support over health information technology when they are given the option, and older adults with disabilities are willing to give up their privacy for independence, but they need to make informed decisions [63].

Another barrier is that health care technologies can be stigmatizing. This finding was also reported by Mitzner et al [64] and Demiris et al [24] who showed that the fear of stigma can prevent older adults from embracing and using technology. According to Blythe et al [65], a design with the potential to stigmatize its users reinforces a particular view of older adults’ place in society. For example, studies have revealed that wearable sensor devices or personal emergency alarms have a negative image among older individuals because they are conspicuous, identifiable as a care item, and even humiliating [66,67]. The fear of stigmatization or of being labeled as disabled or sick influences the adoption and use of health care devices. Stigma may become less of a concern for older adults when the need to use health care technologies becomes urgent [62]. Therefore, older adults are more likely to adopt technologies that they do not view as stigmatizing, such as smart watches, which are widely used and not immediately identifiable as a health care device.

Our result related to the cost of the technologies is consistent with that of previous studies that have mentioned cost as a barrier to overcome and affect the use of technologies to assist health care such as health information and assistive technologies [46,50,62,66,68]. It is important that technologies are affordable; otherwise, older adults would drive away from using technology [37].

The lack of familiarity is another barrier mentioned. These findings support evidence from a previous study on health information technologies such as telecare, electronic health record, decision support systems, and assistive information technologies, which found issues with familiarity as a barrier.
that older adults face when using technology [63]. In addition, some studies showed that some older adults with minimal technology experience prefer to rely on health care providers and carers for health tracking [69,70].

Our last finding related to perceived need supports evidence from previous studies, in which perceived need for the technology is a variable that could influence the adoption of new technologies [23,25,71-73], and it has been shown to be a significant factor in the acceptance of assistive technologies [74]. However, our findings do raise the question of why older people continue to use technology despite the presence of barriers. One reason is that the perceived need trumps the barriers to using technologies. Our participants were using health care technologies because there is a perceived need that motivates them to overcome perceived barriers. For example, even if they feel overloaded with information, they will continue to use technology because it helps manage their health. Although this suggests that older adults will tolerate these barriers if the need outweighs them, technology designers should focus on alleviating barriers to promote the uptake of technologies for health self-management by older adults.

Limitations and Future Work

One limitation of our study is the wide age range of the participants, spanning 20 years. This included, presumably, recent retirees (ie, those in their 60s) and those approaching advanced age. There is a significant difference between these 2 groups regarding needs and capabilities.

Second, most participants (20/22, 91%) had tertiary education, and this is not a representative sample. Previous studies have shown that a person’s level of education was significantly associated with technology acceptance [75-77]

A third limitation is that this study provides an overview of factors but does not differentiate these factors between types of health self-management technologies. Therefore, the results may not be specific for each technology mentioned in this study.

Finally, the data for this study were collected during the COVID-19 pandemic. Owing to the restrictions imposed to prevent the spread of the virus, older adults had to access telehealth through videoconferences or consultation calls to access medical care [78]. Telehealth was the most common technology used by the interviewees, and some barriers related to the use of telehealth prevailed. Future studies could be carried out in nonpandemic times and could perhaps highlight other findings related to the barriers to using and accessing technologies other than telehealth.

Conclusions

This study investigated the use of digital technologies for self-management of health by older adults. On the basis of the range of technologies that support older adults’ health, we argue that some participants showed a resilient attitude, taking early measures to monitor their health and stay active, for which they were more willing to use technology. In addition, we argue that older adults’ perceived need outweighs technological barriers, so they will continue using the technology if it gives them value. We also found social and organizational influence to be one of the most mentioned enablers of the use of technologies.

The analysis of the interviews provides useful information for the design and implementation of future technologies for the self-management of health. Future studies could explore resilience, as this study shows evidence related to resilience that could influence the use of technologies for health self-management. In addition, we argue that it may be necessary to help people gain resilience in the face of future health decline before introducing health care technologies.

Finally, technology providers could investigate the social and organizational influence and incorporate their findings in technology design as this factor affects the adoption of technologies. They could also explore older adults’ motivations to use technologies and reduce the barriers that they face.

Acknowledgments

The authors would like to thank all interviewees for their contributions to the study.

Authors’ Contributions

This study was conceived by EGR, JW, and GB. EGR, JW, and GB designed this study. EGR collected the data. EGR conducted the data analysis. EGR, RMK, JW, and GB drafted the manuscript. All authors provided input to the final version of the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Interview participants.

[DOCX File, 20 KB - aging_v6i1e43197_app1.docx ]

References


LaMonica HM, Davenport TA, Roberts AE, Hickie IB. Understanding technology preferences and requirements for health information technologies designed to improve and maintain the mental health and well-being of older adults: participatory design study. JMIR Aging 2021 Jan 06;4(1):e21461. [doi: 10.2196/21461] [Medline: 33404509]


Fischer SH, David D, Cotty BH, Dierks M, Safran C. Acceptance and use of health information technology by community-dwelling elders. Int J Med Inform 2014 Sep;83(9):624-635 [FREE Full text] [doi: 10.1016/j.ijmedinf.2014.06.005] [Medline: 24996581]


Abbreviations

CPAP: continuous positive airway pressure
Refined Analysis of Older eHealth Users From an Agency Perspective: Quantitative Telephone Interview Study

Esther Brainin1*, PhD; Efrat Neter1*, PhD

Ruppin Academic Center, Department of Behavioral Sciences, Faculty of Community and Social Sciences, Emek Hefer District, Israel

* all authors contributed equally

Corresponding Author:
Esther Brainin, PhD
Ruppin Academic Center
Department of Behavioral Sciences
Faculty of Community and Social Sciences
Emek Hefer
Emek Hefer District, 4025000
Israel
Phone: 972 98983015
Email: estherb@ruppin.ac.il

Abstract

Background: Most studies on the eHealth divide among older people have compared users to nonusers and found that age, gender, and education were associated with eHealth misuse. They assumed that these characteristics were structural barriers to eHealth adoption. Furthermore, eHealth practices have been examined in a narrow and incomplete way, and the studies disagree about the association between health conditions and eHealth use. Using a more dynamic theoretical lens, we investigated the potential motivations driving older adults’ agential adoption of eHealth practices despite their advanced age.

Objective: This study aimed to obtain a complete and detailed description of eHealth uses among older adults; examine whether demographic characteristics such as age, gender, and education (previously related to eHealth misuse) are still associated with the various eHealth clusters; and determine whether contextual factors such as changes in the health condition of older eHealth users or their loved ones are associated with older adult eHealth use.

Methods: We conducted a 30-minute telephone interview with a representative sample of 442 Israeli adults (aged ≥50 years) with a sampling error of 2.04%. The interviews were conducted in Hebrew, Arabic, and Russian. Using factor analysis with 21 eHealth use questions, we identified 4 eHealth clusters: instrumental and administrative information seeking, information sharing, seeking information from peers, and web-based self-tracking. In addition to age, gender, education, internet experience, frequency of internet use, perceived eHealth literacy, and self-rated health, we asked respondents to indicate how much they had used offline health services because of a health crisis in the past year.

Results: We found differences in the number of older eHealth users in the various clusters. They used instrumental and administrative information (420/442, 95%) and obtained information from peers (348/442, 78.7%) the most; followed by web-based self-tracking related to health issues (305/442, 69%), and only a few (52/442, 11.3%) uploaded and shared health information on the web. When controlling for personal attributes, age, gender, and education were no longer predictors of eHealth use, nor was a chronic ailment. Instead, internet experience, frequency of internet use, and perceived eHealth literacy, and self-rated health were associated with 3 eHealth clusters. Looking for health information for family and friends predicted all 4 eHealth clusters. For family and friends predicted all 4 eHealth clusters.

Conclusions: Many older adults can overcome structural barriers such as age, gender, and education. The change in their or their loved ones’ circumstances encouraged them to make deliberate efforts to embrace the new practices expected from today’s patients. Seeking health information for family and friends and dealing with unexpected health crises motivates them to use eHealth. We suggest that health professionals ignore their tendency to label older people as nonusers and encourage them to benefit from using eHealth and overcome stereotypical ways of perceiving these patients.

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KEYWORDS
eHealth; health; internet; structuration theory; agency; digital divide; age; gender; education; information; health condition; self-rated health; SRH; health care services; surrogate; older adults; users; patient; Giddens; Archer; Bourdieu; capital
Introduction

Background

Age is a well-known predictor of the eHealth divide [1-4]. However, there is mounting evidence that older people, particularly those in high-income countries, are among the fastest-growing users of eHealth [5-7]. Our study sought to portray a diverse range of eHealth uses among older adults; explain what trajectories might have led to this shift in eHealth use; and find out whether age, gender, and education (previously predicting non-eHealth use) will be associated with the amount of eHealth use among older adults. To that end, we proposed to rely on a different theoretical lens than the one used by most previous studies on the gray eHealth divide and conduct a study only among older eHealth users. Our study filled these gaps by addressing four objectives as follows: (1) to obtain a comprehensive and detailed description of eHealth uses among older adults and classify them into clusters; (2) to examine whether demographic characteristics such as age, gender, and education (previously associated with eHealth misuse) continue to be associated with the different eHealth clusters; and (3) and (4) to find out which contextual factors, such as older eHealth users’ and their loved ones’ changing health conditions, are associated with their use of eHealth in the different clusters.

Study Novelty and Knowledge Gaps

Most studies on the eHealth divide have explained why there are differences between older people who use eHealth and those who do not. However, they have ignored the possibility of a change in this practice trajectory. The Bourdieusian theoretical framework has been used in many studies to explain this divide [2,8-10]. However, this line of explanation has been criticized as being too deterministic and rigid [11,12]. We proposed that the structuration theory by Giddens [13,14] can explain this transition as he argues that social structure forces (such as belonging to the older age group [15] and being reluctant to use the internet) can be changed through a process of internal deliberation that people (agents) are doing when they face changes in their lives’ contexts. They have the freedom to modify their own goals in relation to their changing context, choose projects, and translate them into new practices [16]. Bourdieu [8] and Giddens [13,14] differ in how they view social actors’ conscious intentions. For Giddens [13,14], actors are reflexive; they can reflect on their actions and identities and act accordingly [17]. He defines agency as the ability and deliberateness to achieve goals through a conscious reflection on one’s habitus [18-20]. In his view, context matters as it sets social expectations; makes agents reflect on their daily behavior; and may encourage them to modify their goals and embrace social expectations, especially in unforeseen situations [21]. Although this study is neither causal nor longitudinal, we explained the 2 things that have changed in the context of health service use in recent years: the social expectations regarding a patient’s role [22] and pervasive internet access. Laypeople have gained technical and medical knowledge, skills, and expertise through the media and new technologies, resulting in lay reskilling encouraged by the availability of electronic information, policy makers, and institutions [23,24]. It reconstructed the new patient’s identity [25] and set new social expectations for powerful autonomy. These changes were intertwined with internet penetration, suggesting that the first digital divide related to access has been closed [26], and thus, obtaining health information on the web became a proactive behavioral adaptation to later-life health challenges [27-29], representing an agentic approach to positive health behaviors and self-care [30]. To study the use of eHealth as an agentic behavior among older adults, we need a much more detailed and nuanced elaboration of the term eHealth as, although it is nearly 20 years old, we found a narrow operationalization and little consistency in how eHealth was defined and measured in the scientific literature on older adults’ eHealth use.

Defining eHealth

We looked at quantitative studies published in the last 10 years that examined eHealth use among middle-aged and older adults using large, population-representative survey data sets (Multimedia Appendix 1 [1,3-6,31-38]). There were 77% (10/13) of the studies that examined eHealth use as a predicted variable and 23% (3/13) of the studies that examined it as a predictor variable. Most of the studies (9/13, 69%) in Multimedia Appendix 1 were conducted in the United States, with the rest being conducted in Poland, Israel, and Sweden. Most studies (10/13, 77%) measured eHealth as the predicted variable to identify its predictors, which explain its association with offline health service use [6], better self-care and users’ empowerment [4], and medical satisfaction [31]. Some studies (2/13, 15%) defined eHealth use as “health information technology” [6,32], whereas others (1/13, 8%) defined it as “using social media for health-related activities” [33]. With some similarities, each study used 1 to 5 questions about eHealth use. In total, 77% (10/13) of the studies examined whether respondents looked on the web for general health information (about health or illness) [5]. The second most frequently asked question was whether respondents had used the internet to schedule a medical appointment [32], deal with health insurance [3], or refill a prescription [34] or whether they had contacted their medical provider directly [1]. Respondents were asked if they had sought health information [3], started or joined a health-related support group [35], or used chat groups to learn about health topics (3/13, 23%). Only 8% (1/13) of the studies examined whether participants kept a health-related diary or blog [35]. To conclude, recent research on eHealth use among middle-aged and older adults has revealed an incomplete and limited picture of the potential eHealth use. Thus, the first and second research questions of our study filled these gaps. First, we obtained a comprehensive and detailed description of the various eHealth uses among older adults. Second, we determined whether demographic characteristics such as age, gender, and education (previously related to non-eHealth users) continue to be associated with the use of eHealth in the different clusters. Notwithstanding, apart from the rich eHealth options available to users, there is another contextual factor that might facilitate nonusers’ transition to become users—users’ or their loved ones’ unexpected changes in health condition.
Measuring Health Condition Change Through Health Care Use

There was conflicting evidence related to the association between health status and eHealth use. People with chronic conditions, disabilities, or low self-rated health (SRH) were most likely to seek out and act on health news and information [39,40]. This was true for older participants as well [1,32,36,40]. In contrast, other studies found that web-based health information seekers were mostly healthy [2,41,42]. A study on older adults found no relationship between eHealth use and SRH [36]. A recent longitudinal, 2-cycle study explored the relationships among chronic conditions (representing health status), eHealth use, and health care use [6]. Both study cycles showed an association between eHealth use and physician visits (including emergency room or clinic visits); however, the association was stronger in the first cycle, when they were coterminous. The use of eHealth information was also linked to fewer physician visits among participants with 1 in 5 chronic conditions (diabetes). Wicks et al [43] found a negative relationship between eHealth use and physician visits. In total, 2 recent studies examined eHealth use before and after visiting a health care provider and health care use, which was not measured using physician visits. According to these studies, eHealth empowers patients and improves self-care and health perceptions [4,31]. In this study, we assumed that eHealth use can have a more crucial effect among those who experience a change in their own or a loved one’s health [4], especially among the older population. As the focus of this study was on cases in which a change in one’s own or a loved one’s health condition served as a potential stressor [44], which facilitates the emergence of active eHealth users, it was important to conceptualize and measure changes in health status. The aforementioned studies used different health measures. Some studies used the total number of chronic illnesses diagnosed (followed by a list of the most common chronic illnesses), whereas others asked respondents to self-report activity restrictions and memory issues, among other things. It was suggested that the SRH responses may be sensitive to the wording of both the question and the response options [45]. It was not linked to eHealth after demographic variables were considered [33], and its measure may reflect a general estimation of one’s health condition related to a given period, disregarding any coincidental or random episode of change in one’s health condition that occurred during the research period but was resolved. Thus, although very popular, SRH may not reflect a recent health change. Chronic illness is an irreversible medical condition that may require lifelong adaptation and management, so treatment becomes part of one’s daily routine. To capture major changes in health conditions during a certain period, we proposed using health care use as a proxy. In most cases, such a change requires using the multilayer health care system, such as seeing a general practitioner and a specialist or needing emergency services or hospitalization. Patients with major health changes quickly use the entire system’s layered structures. Given that physicians cannot always satisfy patients’ information needs [41] and that patient autonomy in making treatment decisions is encouraged, turning to eHealth resources may be a stress-buffering agent [44]. It transforms patients from passive health consumers into proactive health producers with knowledge [44]. To support our third research question, we suggested that recent health care use among old eHealth users can provide a thorough and detailed measure of health status change when studying eHealth uses and their relationship to changes in contextual factors of eHealth users that might turn them into active agents who use eHealth intensively.

Knowing Means Participating—Older Adults as Health Information Surrogates

People search for eHealth not only for themselves but also on behalf of others without being asked to do so, often initiating behavior change or influencing health-related decisions [46,47]. Lay information intermediaries, or health information surrogates (HISs), seek information in a self-generated (ie, internally motivated), nonprofessional, or informal capacity, anticipating another person’s needs. These agents, also called hidden patients, are proxy searchers with purposeful, problem-driven behavior [48,49]. A possible motivation for this behavior is another contextual change for the seeker—a loved one’s health change. In such situations, people seek health information on behalf of their family, friends, or colleagues as caregivers or significant others, sometimes at higher rates than they do for themselves [42]. Individuals who seek others’ health-related information can promote better transmission of information and social support [50]. Cutrona et al [46] found that two-thirds (66.6%) of American respondents reported being HISs between 2011 and 2012. Surrogate seekers reported more eHealth activities requiring user-generated content, such as emailing health care providers, visiting social networking sites to read and share medical topics, and joining online health support groups. This number is higher than that of a 2012 Pew Internet Poll (54%) [51]. Europe had similar results. Data from the Flash Eurobarometer on 28 European Union member states showed that 61% of respondents searched for health-related information on behalf of someone else [52]. Middle-aged Europeans were the most likely to report being HISs, whereas the youngest and oldest were the least likely to do so. Despite these findings, the study suggests exploring HISs among older adults aged ≥50 years because of their varied family roles and social engagements. These engagements are part of the eHealth users’ context. The group aged 50 to 64 years may be similar to the European middle-aged group with the most HISs. For users aged ≥65 years, this measure is also important as their generational identity is changing because of increased life expectancy and technology exposure. Most people will spend a longer period of their lives in a 3- to 4-generation family. This age group has considerable demographic and social weight as it can devote more time to intergenerational and friendship help [53-55]. Although studies have explored respondents’ HIS behavior, most of them used general yes-or-no questions without specifying what kind of information they were looking for. Our study filled the gap in the literature by investigating which eHealth practices older adults use that are associated with their HIS behavior.

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(page number not for citation purposes)
Methods

Overview

This study used data collected through telephone interviews using a national random-digital dial-telephone household survey of Israeli adults (aged ≥50 years). The interviews lasted between 25 and 30 minutes. The interviews were conducted in Hebrew, Arabic, and Russian by professional interviewers who went through a special training session to familiarize themselves with the questionnaire’s terminology. After a short introduction, each interviewee was asked whether they agreed to participate in the survey. Those who agreed were then interviewed. The interviewers conducted the telephone survey using computer-assisted telephone interviewing software.

Ethics Approval

This study was approved by the institutional review board of Ruppin Academic Center (2012-1-6). All respondents expressed consent before their participation. Respondents’ anonymity was assured, and they were not asked for any identifying information during the phone survey.

Sample

Calls were placed to 1288 representative residential households, of which 128 (9.94%) were not relevant (eg, disconnected, business, or fax numbers). Of the remaining 1160 households, 603 agreed to be interviewed, representing a 51.98% response rate and a sampling error of 2.04%. The participation criterion for the first survey phase was the respondents’ age (≥50 years). In this phase, there were 34.5% (208/603) of participants who did not use the internet at all, 28.5% (172/603) of participants who used the internet but not for health purposes, and 37% (223/603) of participants who used the internet for health purposes—the eHealth users. All 3 groups were interviewed. To focus on older eHealth users only and portray the extent and scope of eHealth activities on a larger sample, the data collection process followed a second phase using the same methodology as the one used in phase 1 except that the following 2 participation criteria were used: respondents’ age (≥250 years) and respondents’ use of the internet for health-related purposes. In phase 2, only participants who met the 2 criteria were interviewed. As a result, of the 1139 representative residential households that were contacted, an additional 219 (19.23%) eHealth participants were surveyed, resulting in a sample of 442 eHealth participants.

Design

The explained measures of eHealth activities included 4 clusters: instrumental and administrative information seeking, information sharing, seeking information from peers, and self-tracking. The explanatory variables included demographic variables such as age, gender, education, and marital status; health-related variables such as chronic ailments, seeking information for family and friends, and offline health care use; and internet use frequency, experience, and skills.

Measures

Clusters of eHealth Activities

eHealth activities were explored using 21 questions that examined participants’ detailed engagement in web-based health-related activities. A total of 10 items were measured using a 5-point frequency scale (1=never; 5=several times a week) in response to the following question: “How often did you use the Internet for the following health issues?” A total of 11 items were measured using a dichotomous yes-or-no scale in response to the following question: “Did you engage in the following online health-related activities in the past twelve months?” Subsequently, using principal component analysis with varimax rotation, eHealth activities were clustered into 4 categories, which explained 33.9% of the variance. The 4 clusters of eHealth activities that emerged were instrumental and administrative information seeking (10 items; mean 1.53, SD 0.42; Cronbach α=.73; highest-loading item: “Sought information about long term care for an elderly or disabled person”), information sharing (3 items; mean 1.06, SD 0.19; Cronbach α=.74; highest-loading item: “Posted a review web-based of a particular drug or medical treatment”), seeking information from peers (5 items; mean 1.43, SD 0.32; Cronbach α=.68; highest-loading item: “Sought others who might have health concerns similar to mine”), and self-tracking on the web (3 items; mean 1.42, SD 0.36; Cronbach α=.57; highest-loading item: “Tracked my health indicators or symptoms online”).

Demographic and Health-Related Variables

Participants were asked to provide their age, gender, education, and marital status. We have consistently reported on gender in the manuscript. The gender variable included 2 values. Offline health care use was measured by asking respondents whether they had experienced a major change in their health condition, seen their general practitioner, seen a specialist, sought emergency room services, or been hospitalized in the past year. Responses were provided using a 3-point response scale (1=no; 2=yes, once or twice; and 3=yes, 3 times or more). The possible response score obtainable for this independent variable was between 5 and 15 (mean 7.86, SD 1.86). The chronic ailments variable was measured using a 3-point response scale (1=no chronic ailment, 2=1 or 2 chronic ailments, and 3=3 or more chronic ailments). Health information seeking for family and friends was measured using a dichotomous yes-or-no scale in response to the following question: “For whom have you looked for health information online in the past year? (Yourself, your spouse, children, parents, relatives, friends).” The scale was scored by adding the answers, resulting in a score ranging from 6 to 12 (mean 8.13, SD 1.53).

Internet Use Frequency, Experience, and Skills

Participants’ internet experience was measured by asking respondents to report the number of years since they first began surfing the web (mean 11.02, SD 5.93); the frequency of internet use was measured by asking respondents how often they generally used the internet. Responses were provided using a 7-point scale (1=very seldom; 7=every day, all day; mean 5.71, SD 1.02). eHealth literacy was measured using the eHEALS tool [56]. The scale comprises 8 items evaluated on a 5-point
Likert scale (1=strongly disagree; 5=strongly agree; mean 3.1, SD 0.83; Cronbach α=.90; sample item: “I know how to find helpful health-related resources on the Internet”). The scale was previously translated into Hebrew [10].

Data Analysis

First, the sample’s demographic and background characteristics and the eHealth cluster activities were described using descriptive statistics. Second, Pearson correlations between the 4 eHealth clusters of activities and all other variables were computed. Third, hierarchical multiple linear regression analyses were carried out on the 4 eHealth clusters of activities. Age, gender, education, and marital status were entered in the first step, and health-related variables, internet use frequency, experience, and skills were entered in the second step. Each step presents its contribution to the explained variance. The analyses were conducted using SPSS Statistics (version 23; IBM Corp).

Results

Sample Demographic and Background Characteristics

The characteristics of the participants are presented in Table 1. The sample comprised 63.1% (279/442) women and 95.2% (421/442) Jewish participants. Participants’ age ranged from 50 to 87 years with a mean age of 61.05 (SD 8.23) years. The mean age of the men participants was considerably higher than that of women participants (mean 62.2, SD 8.85 vs mean 60.38, SD 7.77, respectively; \( F_{1,439}=5.07; P=.03 \)). Approximately half (225/442, 50.9%) of the sample had postsecondary education, and 74.4% (329/442) were married. A total of 38% (168/442) of the participants reported one or more chronic ailments.
Table 1. Demographic profile of older eHealth users (n=442).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Participants, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>163 (36.9)</td>
</tr>
<tr>
<td>Women</td>
<td>279 (63.1)</td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
</tr>
<tr>
<td>50-54</td>
<td>116 (26.2)</td>
</tr>
<tr>
<td>55-59</td>
<td>98 (22.2)</td>
</tr>
<tr>
<td>60-64</td>
<td>91 (20.6)</td>
</tr>
<tr>
<td>65-69</td>
<td>65 (14.7)</td>
</tr>
<tr>
<td>70-74</td>
<td>33 (7.5)</td>
</tr>
<tr>
<td>75-84</td>
<td>38 (8.6)</td>
</tr>
<tr>
<td>Education</td>
<td></td>
</tr>
<tr>
<td>Secondary education</td>
<td>215 (48.6)</td>
</tr>
<tr>
<td>Postsecondary and tertiary education</td>
<td>225 (50.9)</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
</tr>
<tr>
<td>Single, divorced, or widowed</td>
<td>96 (21.7)</td>
</tr>
<tr>
<td>Married</td>
<td>329 (74.4)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
</tr>
<tr>
<td>Jewish</td>
<td>421 (95.2)</td>
</tr>
<tr>
<td>Arabic</td>
<td>21 (4.8)</td>
</tr>
<tr>
<td>Health condition—chronic ailments</td>
<td></td>
</tr>
<tr>
<td>No chronic ailments</td>
<td>262 (59.3)</td>
</tr>
<tr>
<td>One or more chronic ailments</td>
<td>168 (39)</td>
</tr>
<tr>
<td>Health condition—change in health condition in the past 12 months</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>214 (48.4)</td>
</tr>
<tr>
<td>Yes</td>
<td>221 (50)</td>
</tr>
<tr>
<td>Internet use frequency</td>
<td></td>
</tr>
<tr>
<td>Once a week or less</td>
<td>14 (3.2)</td>
</tr>
<tr>
<td>Several times a week</td>
<td>48 (10.9)</td>
</tr>
<tr>
<td>Once a day</td>
<td>49 (11.1)</td>
</tr>
<tr>
<td>Several times a day</td>
<td>261 (59)</td>
</tr>
<tr>
<td>All day, every day</td>
<td>69 (15.6)</td>
</tr>
</tbody>
</table>

Clusters of eHealth Activities

To obtain a comprehensive and detailed description of eHealth practices among older adults, we divided the sample into 6 age groups. As explained in the Methods section, different numbers of activities were classified into each of the 4 eHealth clusters. The clusters of eHealth uses and the amount of users in the various age groups are presented in Table 2.

For every cluster of eHealth practices, we calculated the percentage of participants of different age groups, and the mean percentage of all age groups is also displayed. Table 2 shows that, for instrumental and administrative information seeking, the practice rate was the highest, ranging from 88% (29/33) for the age group of 70 to 74 years to 97% (95/98) for the age group of 55 to 59 years, with a mean use of 94% (SD 3.20%). Next was the seeking information from peers cluster, ranging from 85% (28/33) for the age group of 70 to 74 years to the lowest percentage (27/38, 71%) for the oldest age group of ≥74 years (mean use 79%, SD 4.86%). The third cluster of use was self-tracking on the web, ranging from 74% (48/65) for the age group of 65 to 69 years to 63% (62/98) for the age group of 55 to 59 years. The mean use for this cluster was 69% (SD 4.83%). The least frequent uses of eHealth were in the information-sharing practices cluster, ranging from 13.8% (16/116) for the youngest age groups to 3% (1/38) for the oldest. Only a mean of 11% (SD 4.87%) of participants used eHealth in this cluster. We can see that there are few differences in the
percentage of users between age groups within each cluster. However, there are significant differences in the percentage of users between clusters.

Table 2. Clusters of eHealth practices by different age groups.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Age group (years), n (%)</th>
<th>Value (%), mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50-54 (n=116)</td>
<td></td>
</tr>
<tr>
<td>Instrumental and administrative information</td>
<td>55-59 (n=98)</td>
<td>94 (3.20)</td>
</tr>
<tr>
<td></td>
<td>60-64 (n=91)</td>
<td>n (95)</td>
</tr>
<tr>
<td></td>
<td>65-69 (n=65)</td>
<td>n (95)</td>
</tr>
<tr>
<td></td>
<td>70-74 (n=33)</td>
<td>29 (88)</td>
</tr>
<tr>
<td></td>
<td>≥74 (n=38)</td>
<td>n (95)</td>
</tr>
<tr>
<td>Seeking information from peers</td>
<td>n (78)</td>
<td>79 (4.86)</td>
</tr>
<tr>
<td>Self-tracking on the web</td>
<td>n (66)</td>
<td>69 (4.83)</td>
</tr>
<tr>
<td>Information sharing</td>
<td>16 (14)</td>
<td>11 (4.87)</td>
</tr>
</tbody>
</table>

Pearson Correlations Between the 4 eHealth Clusters and All Other Variables

The intercorrelations between the 4 clusters of activities and all independent variables are displayed in Table 3. We can see from the table that the 4 eHealth clusters are significantly associated with each other at moderate to high levels so that the more one engages in one cluster of activity, the more likely it is that one engages also in the other activities. Instrumental and administrative information seeking had significant positive correlations with the other 3 eHealth activities: information sharing ($r=0.31; P<0.001$), seeking information from peers, ($r=0.38; P<0.001$) and self-tracking ($r=0.48; P<0.001$). The correlations between information sharing and seeking information from peers and self-tracking activities were statistically significant but at a lower value ($r=0.21$ and $P<0.001$ vs $r=0.16$ and $P<0.001$, respectively). Seeking information from peers was also correlated with self-tracking at a moderate level ($r=0.37; P<0.001$). Despite the large scale of the sample age, there were no significant correlations between age and the 4 eHealth activities, nor were they associated with gender, except for seeking information from peers. Women were found to use information from peers more than men ($r=0.13; P=0.01$), and education was significantly associated with 3 eHealth activities except for information sharing. Married respondents were significantly more likely to use information from peers ($r=0.13; P=0.01$). Only 2 of the 3 health-related conditions were significantly correlated with eHealth activities such that health care use and health information seeking for family and friends were significantly correlated with the 4 clusters of eHealth activities and chronic ailments was not. The correlations for health care use were $r=0.13 (P=0.01)$ with instrumental information seeking, $r=0.11 (P=0.05)$ for information sharing, $r=0.21 (P<0.001)$ for seeking information from peers, and $r=0.17 (P<0.001)$ for self-tracking. The highest correlation of health information seeking for family and friends was with seeking information from peers ($r=0.45; P<0.001$), followed by instrumental information seeking ($r=0.39; P<0.001$), self-tracking ($r=0.27; P<0.001$), and information sharing ($r=0.12; P=0.01$). Offline health care use (which served as a proxy for health condition change) was also statistically significant and positive for all 4 eHealth activities but at a lower level. The highest correlation was between offline health care use and seeking information from peers ($r=0.21; P<0.001$), followed by self-tracking activities ($r=0.17; P<0.001$), instrumental information seeking ($r=0.13; P=0.01$), and information sharing ($r=0.11; P=0.05$).

The 3 variables related to internet use frequency, experience, and eHealth literacy were positively correlated with eHealth activities except for information sharing. eHealth literacy had the highest correlation with seeking information from peers ($r=0.43; P<0.001$), followed by instrumental information seeking ($r=0.40; P<0.001$), self-tracking activities ($r=0.26; P<0.001$), and information sharing ($r=0.10; P=0.05$). Internet use frequency was positively associated with instrumental information seeking ($r=0.24; P<0.001$), followed by self-tracking activities ($r=0.18; P<0.001$) and seeking information from peers ($r=0.16; P<0.001$).
Table 3. Correlation analysis (Pearson r and 2-tailed P value) between all the study variables.

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aNot applicable.
Hierarchical Multiple Linear Regression Analyses on eHealth Clusters of Activities

Overview
Regression analysis of eHealth activities explored whether the health-related variables, internet use characteristics, and eHealth activities were associated with the 4 clusters of activities after controlling for the demographic variables age, gender, education, and marital status. The results are presented in Tables 4 and 5.

Table 4. Hierarchical regression analysis for variables predicting 2 clusters of web-based health activities (n=405).

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<th>Explanatory variables</th>
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<th>Information sharing (health Web 2.0)^b</th>
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<td>B (SE)</td>
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<td>Education</td>
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<td>Offline health care use</td>
<td>0.021 (0.01)</td>
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<td>Chronic ailments (none)</td>
<td>0.031 (0.033)</td>
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<td>Information seeking for family and friends</td>
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<td>Internet use frequency</td>
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<tr>
<td>eHealth literacy</td>
<td>0.126 (0.025)</td>
<td>.254^e</td>
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^aR^2=0.26; F_{10,395}=14.08 (P<.001).
^bR^2=0.6; F_{10,394}=2.59 (P=.005).
^cP<.05.
^dP<.01.
^eP<.001.

Table 5. Hierarchical regression analysis for variables predicting 2 clusters of web-based health activities (n=405).

<table>
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<th>Health-related web-based self-tracking^b</th>
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<tr>
<td>Education</td>
<td>−0.002 (0.010)</td>
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<tr>
<td>Gender (men)</td>
<td>0.031 (0.028)</td>
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<td>Marital status (not married)</td>
<td>0.112 (0.033)</td>
<td>.147^c</td>
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<td>Offline health care use</td>
<td>0.030 (0.008)</td>
<td>.174^c</td>
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<td>0.013 (0.024)</td>
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<tr>
<td>eHealth literacy</td>
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^aR^2=0.34; F_{10,395}=19.91 (P<.001).
^bR^2=0.15; F_{10,395}=6.91 (P<.001).
^cP<.001.
^dP<.01.
**Instrumental and Administrative Information Seeking Cluster**

In Table 4, we see that the first step of the demographic variables predicted only 4% of the instrumental and administrative information seeking variance ($F_{4,401}=3.93; P=.004$). The health-related variables in the second step added 13% to the explained variance ($F_{7,398}=13.86; P<.001$), and the internet use characteristics in the third step added 7% to the explained variance ($F_{10,398}=14.08; P<.001$). The regression coefficients reported are those of the third step. Only offline health care use ($\beta=.09; t_{395}=1.91; P=.06$), health information seeking for family and friends ($\beta=.27; t_{395}=5.55; P<.001$), frequency of internet use ($\beta=.09; t_{398}=1.94; P=.05$), and eHealth literacy ($\beta=.25; t_{395}=5.00; P<.001$) were found to be significantly associated with instrumental and administrative information seeking such that the more participants used offline health care services, looked for health information for family and friends, used the internet frequently, and had high eHealth literacy, the more they sought instrumental and administrative information.

**Information Sharing Cluster**

The first step of the demographic variables predicted only 1% of the information sharing variance ($F_{4,400}=0.61; P=.65$). The health-related variables in the second step added 3% to the explained variance ($F_{7,398}=3.25; P=.002$), and the internet use characteristics in the third step added 2% to the explained variance ($F_{10,394}=2.59; P=.005$). The regression coefficients reported are those of the third step. Only offline health care use ($\beta=-.17; t_{394}=3.05; P=.002$) and health information seeking for family and friends ($\beta=1.13; t_{394}=2.32; P=.02$) were found to be significantly associated with information sharing such that the more participants used offline health care services and looked for health information for family and friends, the more they shared health information on the web.

**Information Seeking From Peers Cluster**

Table 5 shows that the first step of the demographic variables predicted only 5% of the information seeking from peers variance ($F_{4,401}=5.35; P<.001$). The health-related variables in the second step added 21% to the explained variance ($F_{7,398}=20.03; P<.001$), and the internet use characteristics in the third step added 8% to the explained variance ($F_{10,395}=19.91; P<.001$). The regression coefficients reported are those of the third step. Marital status ($\beta=1.15; t_{395}=3.49; P<.001$), offline health care use ($\beta=1.17; t_{395}=3.80; P<.001$), health information seeking for family and friends ($\beta=3.30; t_{395}=6.40; P<.001$), and eHealth literacy ($\beta=3.11; t_{395}=6.32; P<.001$) were found to be significantly associated with information seeking from peers such that married participants who more frequently used offline health care services, looked for health information for family and friends, and had a higher level of eHealth literacy sought information from peers to a larger extent.

**Self-tracking Cluster**

Finally, in Table 5, we see that the first step of the demographic variables predicted only 3% of the self-tracking variance ($F_{4,401}=3.06; P=.02$). The health-related variables in the second step added 10% to the explained variance ($F_{7,398}=8.38; P<.001$), and the internet use characteristics in the third step added 2% to the explained variance ($F_{10,395}=6.91; P<.001$). The regression coefficients reported are those of the third step. Only offline health care use ($\beta=1.14; t_{395}=2.75; P=.006$) and health information seeking for family and friends ($\beta=.21; t_{395}=3.92; P<.001$) were found to be significantly associated with self-tracking such that the more participants used offline health care services and looked for health information for family and friends, the more they performed self-tracking activities.

**Comparing the 4 Clusters**

Instrumental information consumption was more prevalent among participants who had looked for health information for their relatives and friends and used the health care system in the past 12 months, especially among those with high eHealth literacy and frequency of internet use. These nonmaterial capitals helped users navigate the web and consume the information they needed to perform causal interventions for themselves or their loved ones, as opposed to the information sharing cluster (using Web 2.0 applications), which was the least prominent cluster of web-based health-related activities. The seeking information from peers cluster is a source of human capital as we exchange lay interpersonal knowledge and experience, which was also more prominent among participants who had used the health care system in the past 12 months with greater frequency and had high eHealth literacy. This activity is important as people are more likely to be receptive to information shared by others who are like them [57]. Participants used eHealth in the web-based self-tracking cluster to a lesser degree than in the previous 2 clusters, but it was more prominent among participants who had used the health care system in the past 12 months more frequently than their cohorts. The frequency of internet use and high eHealth literacy were found to have a positive impact on self-tracking on the web.

**Discussion**

**Principal Descriptive Findings**

**Overview**

Most studies on the eHealth divide among older adults in the past 10 years have compared users with nonusers [3,5]. We adopted the structuration theory and focused only on older eHealth users to explore the “full half glass” of internet use for health purposes. We wanted to understand the possible facilitators that encourage older adults’ agential adoption of eHealth practices despite their older age. Such findings are essential as older people, especially in high-income societies, constitute the fastest-growing internet user group.

**First Research Question**

Our descriptive statistics findings provided the answer to our first research question by obtaining a detailed description and portraying the diverse eHealth practices that older adults perform. Although previous studies used only 1 to 5 questions to measure eHealth practices among older adults [32,35], we...
used 21 questions. We created 4 eHealth clusters following a factor analysis procedure: instrumental and administrative information seeking, seeking information from peers who share the same health situation, web-based self-tracking, and uploading and sharing health information. These clusters served as the multipredicted variables in the multilevel analysis. Older adults used eHealth in the instrumental and administrative information cluster the most (29/33, 88% to 95/98, 97%), followed by 71% (27/38) to 85% (28/33) who obtained information from peers who shared the same health situation. Between 62% (61/98) and 77% (71/92) of the participants used eHealth in the third cluster, web-based self-tracking, whereas the least frequent cluster was uploading and sharing health information on the web (1/38, 3% to 5/33, 15%). The correlation analysis among the 4 eHealth clusters showed a small ($r_{422}=0.16$) to medium ($r_{430}=0.48$) association among the 4 eHealth clusters, suggesting that they are not entirely distinct.

**Second Research Question**

The second research question asked whether classic personal characteristics such as age, gender, and education were associated with older adults’ use of eHealth in the different clusters. We answered this question by using descriptive, bivariate, and multilevel statistical analyses. As age was the most prevalent predictor of eHealth use or nonuse in most previous studies, we used descriptive statistics to compare each eHealth cluster across 6 age groups. Our comparison revealed that the differences in eHealth use among the 4 clusters were greater than the differences within each eHealth cluster, specifically among the 6 age groups. Age was not a significant predictor of any of the 4 eHealth clusters despite the sample’s large age range. Gender was also insignificant except for the seeking information from peers cluster, which had more women than men participants. All clusters except for information sharing were significantly correlated with education (albeit at a very low value). In addition to the demographic variables, we checked the correlation between the 4 eHealth clusters and the 3 dimensions of internet use: frequency, experience, and eHealth literacy. We found that these variables were significantly associated with the eHealth clusters except for the information sharing cluster. This implies that the more experienced and confident the user is, the more they use most eHealth practices.

**Third Research Question**

To answer the third research question of whether changes in health circumstances are associated with older adults’ use of eHealth in the different clusters, we correlated the 4 eHealth clusters with chronic ailments and recent offline health care use. In contrast to offline health care use, chronic ailments were not associated with any of the eHealth clusters, suggesting that offline health care use expresses a change in the respondents’ health condition in the months that preceded the study. The more respondents used offline health care services, the more they used eHealth in the 4 clusters.

**Fourth Research Question**

The fourth research question was whether looking for health information for family and friends was associated with the 4 eHealth clusters. The literature suggests that, when family and friends experience changes in their health condition, their surrounding circles help them find more information even without being asked to do so. Such behaviors are referred to as HIsSs. The correlation between the 4 eHealth clusters and the variable “looking for health information online for respondents’ spouses, other family members, and friends” was high and significant.

**Multilevel Analysis Findings**

The multivariate analysis revealed more distinct findings. In the first step, we found that the 3 classic background characteristics—age, gender, and education—were no longer significant predictors of the 4 eHealth clusters among eHealth users. Their contribution to the clusters’ explained variance was meager. This finding answers our second research question. In the second step of the multilevel analysis, we found that 2 of the 3 health condition variables were significant predictors of using eHealth in the different clusters. Offline health care use and health information seeking for family and friends can be framed as contextual health situations. We found that these contextual health situations significantly predicted, across a diverse range, all 4 eHealth clusters after controlling for the demographic characteristics. They contributed the most (21%) to the looking for information from peers cluster, followed by the instrumental and administrative information consumption cluster (15%), the web-based self-tracking cluster (10%), and the information uploading and sharing cluster (3%). These findings suggest that changes in participants’ and their loved ones’ health conditions are strongly associated with the use of eHealth in 3 of the 4 clusters. The more they used offline health care services in the 12 months preceding the survey and the more they served as HIsSs, the more they used eHealth in the 3 clusters. These findings are in line with those of the longitudinal study by Shim et al [6]. They found that the use of web-based health information was positively associated with concurrent reports of physician visits but not over 2 years. Controlling for demographic characteristics and health context variables, we found in the third step of the multilevel analysis that internet frequency of use significantly predicted only instrumental and administrative information consumption. Internet experience did not predict any of the 4 eHealth clusters, and eHealth literacy was significantly associated only with instrumental and administrative information consumption and looking for information from peers. These variables contributed an additional 7% to 8% to the explained variance of the use of eHealth in the 2 clusters. We suggest that the low number of respondents who uploaded and shared information is associated with the more advanced skills needed to upload and produce content (Web 2.0). For late adopters, posting a review on the web of a particular drug or medical treatment is more challenging than lurking or retrieving information. In addition, sharing their own experience in a time of health crisis would be questionable. A recent study found that patient collaboration in a physician-patient forum depends on the disease type, time commitment, and incentives [15]. Thus, apart from the 2 contextual health conditions that significantly predicted the use of eHealth in the different clusters, all other variables were insignificant, resulting in an overall poor explained variance.
The findings for research questions 1 and 2 suggest that many older adults can overcome structural barriers such as age, gender, and education. These findings are complemented with the results of research questions 3 and 4, suggesting that the context of our participants’ actions matters. Becoming an HIS by seeking health information for family and friends and using offline health care services in the previous months suggests that an unexpected and unplanned change process occurred in older eHealth users’ or their loved ones’ lives. In a health crisis, patients seek professional support and depend on the structure of the health care system. As the health care system in Israel is public and there is no consideration of the cost of offline services, people do not hesitate to use them. As a result, we believe that increasing the use of public health services can serve as a proxy to measure the worsening of a participant’s health condition. These changes in health condition coincide with new social expectations resulting from the role technology plays in patient-physician relationships, the expectation that patients will take increasing responsibility for their health-related decisions, and easy access to health information and services on the internet. Our study emphasized the need to trace potential change processes as, according to the structuration theory, the context of changes (in the health conditions of participants and their loved ones) matters. This establishes new social expectations that cause people to reflect on their day-to-day conduct. This ongoing reflection process might encourage people to make deliberate efforts to solve the demands of their lives [44] and embrace new practices expected from today’s patients, especially when dealing with unexpected and unplanned contingencies. Although our study was neither longitudinal nor experimental, we suggest that these kinds of changes might explain what drove our participants to become eHealth users despite their old age, especially if they perceived themselves as having high eHealth literacy. The insignificant association between being chronically ill and using eHealth in the 4 clusters posits that monitoring and treating chronic illnesses has become part of daily routines for a long time, in contrast to a sudden change in health condition. We suggest that our findings align with findings that those with a particular chronic health condition using web-based health information were significantly associated with fewer physician visits at both time points of their study [6].

Limitations, Strengths, and Future Research

Our study is limited primarily because of its cross-sectional methodology. It is neither a longitudinal study nor experimental. Therefore, the associations reported previously might be bidirectional; however, as we asked respondents to describe their actual health circumstances in the previous year, we assume that eHealth use did not cause older eHealth users to feel a sudden change in their health condition followed by extensive use of offline health care services. We also do not believe that people will look for health information on the web for family and friends unless there is a good reason to do so. Despite including representative residential households, our sample limitations arise from our inclusion criteria. Older adults who experienced severe health decline or limitations in physical capacity and more substantial disabilities would not have participated in such a study. As a result, despite the sample’s extensive age range, the participants’ mean age was lower than the mean age of this group of users in the Israeli population. Multiple eHealth practice measures reflect a more fine-grained and detailed description of eHealth uses among older adults and show that, in certain circumstances, such as when confronted with a new health problem, older adults can reflect on their new situation and choose to adopt new practices and use eHealth to deal with offline challenges through an internal deliberation process. For instance, they can consult with peers with little or no effort to obtain advice and support despite their old age. Nevertheless, our study excluded the measurement of mobile technology uses, especially health apps that are very pervasive today, and opens up new opportunities for diagnosing, monitoring, and managing health problems. These findings have implications for potentially expanding the diverse uses of eHealth among older adults. This implies that health professionals should ignore their tendency to label older people as nonusers and encourage them to benefit from using eHealth by overcoming stereotypical ways of perceiving this population.

Future research should continue to explore eHealth use among the older population as technology constantly changes and evolves and pay attention to the unintended consequences of the digitalization of health and health care. Today, it becomes increasingly difficult for patients to resist the demands of being both reflexive and empowered to act. They need to engage with this new world, where patients are required to take increasing responsibility for health-related decisions or exercise agency in this dynamic technological environment that constantly evolves.

Conclusions

Belonging to age groups confers certain advantages and disadvantages through institutional, cultural, and interactional processes that produce and sustain age inequalities [15]. This study focused only on older eHealth users as they have crossed the chasm of being late technology adopters and overcome the structural barrier of belonging to an aged population. The structuration theory by Giddens [13,14] was a better choice to explain our findings as he posits that actors’ reflexivity is a crucial and transformative social process and their agency is only meaningful as subjects. Today, it becomes increasingly difficult for patients to resist the demands of being reflexive and empowered to act. Engaging with this new world requires patients to take increasing responsibility for health-related decisions or exercise agency. That is the attribute that separates the passive patient of 1958 from the active one today. We propose viewing eHealth use among older adults as an important factor, in which people make deliberate efforts to solve problems in their lives. Using eHealth, they express their agency, which can sometimes be challenging for late adopters as the systems are not always user-friendly and fail to provide the needed tailored services, especially in times of pandemics. Health professionals can play a vital role in this change process by encouraging older adults to use eHealth, thus eliminating socially constructed practices that ignore this change and reinforce older adults’ structural barriers.
Acknowledgments
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Data Availability
The data set generated and analyzed during this study is available from the corresponding author upon reasonable request.

Conflicts of Interest
None declared.

Multimedia Appendix 1
eHealth definition and operationalization in studies on older adults.
[DOCX File - aging_v61e40004_appl1.docx]

References


Abbreviations

HIS: health information surrogate
SRH: self-rated health
Health-Seeking Behavior and Its Associated Technology Use: Interview Study Among Community-Dwelling Older Adults

Yichi Zhang1,2, BSc; Edmund W J Lee3, PhD; Wei-Peng Teo1, PhD

1Physical Education and Sports Science Academic Group, National Institute of Education, Nanyang Technological University, Singapore, Singapore
2Ageing Research Institute for Society and Education, Interdisciplinary Graduate Programme, Nanyang Technological University, Singapore, Singapore
3Wee Kim Wee School of Communication and Information, Nanyang Technological University, Singapore, Singapore

Corresponding Author:
Wei-Peng Teo, PhD
Physical Education and Sports Science Academic Group
National Institute of Education
Nanyang Technological University
1 Nanyang Walk
Singapore, 637616
Singapore
Phone: 65 67903704
Email: weipeng.teo@nie.edu.sg

Abstract

Background: Understanding older people’s health-seeking behavior (HSB) is crucial for uncovering their health needs and priorities and developing appropriate policies to address them and avert their disease progression. Technologies play an active role in our daily lives and have been incorporated into health activities to support the older population and facilitate their HSB. However, previous studies of HSB have mainly focused on behaviors during illness, and there are limited studies on how technologies have been used in older people’s health-seeking activities.

Objective: This study aimed to investigate HSB and the associated technology use among the older population, ultimately proposing implications for practice to address their unmet health needs.

Methods: This paper presents partial data from a large qualitative study, which has been approved by the institutional review board and used a phenomenological approach. Semistructured interviews were conducted between April 2022 and July 2022, either via Zoom (Zoom Video Communications Inc) or face-to-face sessions. Inclusion criteria were being aged ≥50 years, long-term residence in Singapore, and being able to speak English or Mandarin. The interviews were manually transcribed verbatim, and thematic analysis was performed, with the individual as the unit of analysis to understand the patterns of behaviors.

Results: In total, 15 interviews were conducted to reach thematic saturation. We identified 5 main consequences of HSB, which were aligned with the original HSB model. Regarding technology use in health seeking, 4 themes were extracted: the most widely used digital technologies are the mobile health apps and wearable devices with the associated wellness programs launched by the government and local companies, and they have the potential to enhance health communication, promote health maintenance, and increase access to health services; information communication technologies and social media, though not primarily designed for health purposes, play a substantial role in easing the process of seeking health information and managing symptoms. Although the outbreak of the COVID-19 pandemic has resulted in some alterations to older adults’ well-being, it has catalyzed the adoption of telehealth as a complement to access health care services, and older adults have different considerations when selecting technologies to facilitate their health seeking and fulfill their health needs. Moreover, 4 archetypes were proposed based on our findings and the insights gained from our participants’ observations in their social networks. These findings led to several implications for practice regarding health communication and promotion, health education, technology design and improvement, telemonitoring service implementation, and solutions to address the needs of each proposed archetype.

Conclusions: Unlike the commonly held belief that older adults resist technologies and lack technological proficiency, our findings showed that technologies could play a promising role in facilitating older adults’ health seeking. Our findings have implications for the design and implementation of health services and policies.

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KEYWORDS

health; health-seeking behavior; aging; technology; telehealth; mobile health; mHealth; eHealth; health access; qualitative study; mobile phone

Introduction

Background

Health-seeking behavior (HSB) is an important concept associated with a country’s health status and economic development [1]. It also helps uncover the health needs and priorities of a population and informs the development of appropriate policies to address their needs and avert their disease progress [2]. In the literature, HSB has been studied with different scopes. The most commonly used definition is “any action or inaction undertaken by individuals who perceive themselves to have a health problem or to be ill for the purpose of finding an appropriate remedy” [3], and studies adopting this definition always examined the formal health system use or the process of illness responses [2,4-6]. However, one could argue that this definition focuses mainly on illness behaviors [7] and ignores the importance of promoting overall health and well-being, as health is not merely the absence of disease or infirmity but rather a state of complete physical, mental, and social well-being [8]. Thus, HSB could be viewed in a broader sense. A more comprehensive definition proposed by Chinn and Kramer is an individual’s deed to the promotion of maximum well-being, recovery, and rehabilitation; this could happen with or without health concerns and within a range of potential to real health concerns [9]. This definition encompasses practices for preserving optimal wellness, preventing illnesses, and addressing any deviation from good health [1,10], which aligns with the concept of universal health coverage [11].

Technologies have been seamlessly integrated into different aspects of people’s life and reshaped people’s health-seeking activities. For instance, smartwatches and wristbands with various sensors can collect continuous biological, behavioral, and environmental data; deliver health interventions; and measure users’ health outcomes [12]. Mobile apps can keep people connected with their families and friends, disseminate health information [13], store and share health and lifestyle data [14], manage chronic diseases [15], and manage medical appointments [16]. Self-test kits, such as Antigen Rapid Test Kits, allow people to obtain results swiftly and conveniently at any location and time [17]. As another example, telemedicine services such as telephone calls and video consultations have also demonstrated their potential to be a cost-effective and efficient alternative solution to access quality health care during the COVID-19 pandemic, by reducing travel time and protecting users from disease transmission [18].

Singapore has one of the fastest-growing older populations in the world owing to the increasing life expectancy and low fertility rates [19,20]. Statistics showed that the proportion of the silver generation in Singapore has been rising from 3.4% in 1970 to 10.4% in 2011 and 17.6% in 2021 [21], and this number is anticipated to reach approximately 23.8% by 2030 [22]. To address this demographic shift, the Singapore government has been constantly exploring technological solutions and launching health initiatives to proactively meet the older population’s health care needs. Some examples include HealthHub—the 1-stop digital health care companion to manage appointments and access personal medical records [23] and National Steps Challenge—the world’s first population-level and fitness tracker–based physical activity that encourages Singapore residents to track their daily moderate to vigorous physical activities and get rewards [24]. Despite these efforts, there remains a scarcity of studies into the patterns of the older population’s HSB and the potential of technologies in facilitating their health seeking and addressing their health needs.

Aim and Objectives

This study aimed to investigate HSB and associated technology use among older people in the Singapore community. We hoped to gain deep insights into how this population makes decisions when they engage with the health system and use technologies; identify any unmet needs; suggest ways in which technology can be leveraged to address these needs; and ultimately, propose recommendations for practical strategies that ensure they are not excluded from the efforts to build the smart nation. In particular, we would like to answer the following research questions:

1. What are the activities of HSB (consequences) in the context of aging in Singapore?
2. How have technologies been incorporated into older people’s health seeking?
3. What considerations do older adults take into account when choosing technologies to meet their health needs?
4. What are the implications for practice?

Methods

This paper presents partial data from a large study that explored the potential of telehealth in addressing unmet health needs and the attitudes toward telehealth among older individuals in the Singapore community.

Study Design

We used a phenomenological approach to explore the lived experiences of older adults’ HSB and associated technology use. The reporting of this study was guided by COREQ (Consolidated Criteria for Reporting Qualitative Research), a 32-item checklist [25].

Participant Recruitment

Inclusion criteria were (1) being ≥50 years old, (2) being Singapore citizens or foreigners who are dwelling in the Singapore community in the long term, and (3) being able to read and converse in English or Mandarin.

The study was planned during the stabilization phase [26,27] (with heightened COVID-19 safety management measures [SMMs] to slow down the rate of transmission), and participant recruitment started in January 2022, during the transition phase...
in Singapore (groups of up to 5 people were allowed in social gatherings) [28]. We aimed to recruit a diverse range of participants in terms of sociodemographic and socioeconomic characteristics such as age groups, ethnicities, education backgrounds, occupations, income levels, and housing types. To achieve this, we adopted convenience sampling with various recruitment strategies, considering the unpredictable SMMs imposed owing to the COVID-19 pandemic. Before data collection, we posted our study posters on social media platforms (Facebook and Instagram) and shared our study information with some chat groups for older adults. We then obtained referrals from our early participants and stopped recruitment until no new themes were identified. Subsequently, we reviewed the profiles of the interviewees and purposively recruited more participants of interest from the community centers and public areas during the COVID-19–resilient nation phase (the social distancing measures were relaxed, and the level of the Disease Outbreak Response System Condition was adjusted to yellow) [29]. We ceased the whole participant recruitment process in July 2022, as no new insights were obtained (thematic data saturation was reached).

Data Collection Tools
This qualitative study used 2 data collection tools—a web-based registration form and a semistructured interview guide.

Web-Based Registration Form
The registration form was used to collect the participants’ sociodemographic and socioeconomic characteristics, existing health conditions, ownership of mobile devices, access to Wi-Fi, and consent to participate in the subsequent interview.

Semistructured Interview Guide
The preapproved interview guide was developed by YZ and reviewed by WPT. In our study, we adopted the definition by Chinn and Kramer [9] and the evolutionary content analysis of HSB by Poortaghi et al [30] in the nursing setting. According to Poortaghi et al [30] HSB has 4 crucial attributes, namely, interactive and processing dimension, intellectual dimension, active and decision-making–based dimension, and measurable dimension (Figure 1). That is, HSB is an ongoing process involving a logical sequence from the symptom evaluation to the decision of using different care, the individual’s efforts to pursue an acceptable level of well-being, the approach to acquiring health information, and the routine of constant health monitoring and behavior change to move toward high-level wellness [30]. The detailed list of guiding questions for the semistructured interviews can be found in Multimedia Appendix 1.

Figure 1. The health-seeking behavior (HSB) model by Poortaghi et al [30].

Data Collection Procedure
Data collection occurred from April 2022 to July 2022. Older adults who expressed interest in participating were invited to complete the web-based registration form and screened to check their eligibility for the interview. Eligible participants were then informed about the data collection procedure; recording of the interviews; and how the data would be analyzed, reported, and protected through written informed consent. Only those who gave their consent were scheduled for an interview. To comply with the SMMs, Zoom (Zoom Video Communications Inc) was chosen as the default interview medium, and a manual was provided to the participants whenever needed. Participants who had unresolvable difficulty with Zoom were offered the option of a face-to-face interview. YZ contacted all eligible candidates either via phone calls or WhatsApp to explain the study details again and scheduled the interviews at their convenience. Written informed consent and permission for interview recording were obtained in advance. Each participant was only required to attend 1 interview session. All interviews were conducted on a one-on-one basis and were video recorded with participants’ consent.

At the beginning of each interview, the study details were explained again, and verbal consent was obtained and recorded. YZ conducted all the interviews. She documented her observations through field notes and confirmed important
findings with the participants during the interviews to ensure accurate interpretations. The interview consisted of 3 sections: HSB, associated technology use, and how the participants selected technologies. Participants received shopping vouchers worth SG $20 (US $15) upon successful completion of the semistructured interview.

**Data Analysis**

Data analysis was performed after each interview. Each participant was assigned a unique identifier before data analysis, and all study data were deidentified during the transcription process. YZ manually transcribed all interviews verbatim in Word (Microsoft Corp) and transferred all text data to Excel (Microsoft Corp) for thematic analysis. Participants who preferred Mandarin had their transcripts translated by YZ and reviewed by WPT, to ensure the highest level of accuracy. The individual was chosen as the unit of analysis to identify the patterns of HSB and technology use in the older population. Next, YZ conducted inductive thematic analysis, in which a line-by-line coding approach was used while reading through the qualitative data. The codes were then categorized based on the research questions, and the generated pattern codes were used to identify themes. YZ and WPT met regularly to discuss the codes and themes until consensuses were reached, to enhance the validity of the analysis.

**Ethics Approval**

This paper presents partial data from a large study, which has been approved by the institutional review board of Nanyang Technological University Singapore (reference IRB-2021-797).

**Results**

**Participant Recruitment and Characteristics**

In the period from February 2022 to April 2022, 12 individuals signed up for our study after seeing our study poster on social media or in the chat groups for older adults, but only 2 (17%) met our inclusion criteria. Additional 8 participants were then recruited via the referral of the initial 2 eligible participants until no further new themes were generated. We subsequently visited different community centers and public areas and recruited 5 participants with low socioeconomic status or from other ethnicities before we reached thematic saturation. In total, we conducted 13 Zoom interviews where participants remained in their homes, and 2 face-to-face interviews were conducted at the community centers in close proximity to the participants’ residences. The mean duration of the interviews in the larger study was 39 minutes (SD 15 minutes 26 seconds).

The 15 participants were aged between 55 and 73 (mean 65.8, SD 6) years, among whom 9 (60%) were women, 13 (87%) were Chinese, 6 (40%) were still working, and 8 (53%) had a personal monthly income of <SG $1000 (<US $752). All participants (15/15, 100%) owned a personal smartphone, but 13% (2/15) of them did not have Wi-Fi access at home. Their characteristics are summarized in Table 1, and detailed information can be found in Multimedia Appendix 2.
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<th>Values, n (%)</th>
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<td>70-80</td>
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<td>Retired</td>
<td>6 (40)</td>
</tr>
<tr>
<td>Employed part-time</td>
<td>4 (27)</td>
</tr>
<tr>
<td>Employed full-time</td>
<td>2 (13)</td>
</tr>
<tr>
<td><strong>Estimated current personal monthly income, SG $ (US $)</strong></td>
<td></td>
</tr>
<tr>
<td>0 (0)</td>
<td>5 (33)</td>
</tr>
<tr>
<td>&lt;1000 (&lt;752)</td>
<td>3 (20)</td>
</tr>
<tr>
<td>1000-1999 (752-1503)</td>
<td>1 (7)</td>
</tr>
<tr>
<td>2000-2999 (1504-2255)</td>
<td>2 (13)</td>
</tr>
<tr>
<td>3000-3999 (2255-3006)</td>
<td>1 (7)</td>
</tr>
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<td>4000-4999 (3007-3758)</td>
<td>2 (13)</td>
</tr>
<tr>
<td>7000-7999 (5263-6014)</td>
<td>1 (7)</td>
</tr>
<tr>
<td><strong>Housing type</strong></td>
<td></td>
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<tr>
<td>Rental flat(^b)</td>
<td>1 (7)</td>
</tr>
<tr>
<td>4-room or 5-room HDB(^c) flat(^d)</td>
<td>4 (27)</td>
</tr>
<tr>
<td>Terrace house(^e)</td>
<td>1 (7)</td>
</tr>
<tr>
<td>Semidetached house(^f)</td>
<td>2 (13)</td>
</tr>
<tr>
<td>Condominium(^g) (excluding executive condominium(^h))</td>
<td>7 (47)</td>
</tr>
<tr>
<td><strong>Ownership of a smart device</strong></td>
<td></td>
</tr>
<tr>
<td>Smartphone</td>
<td>15 (100)</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Values, n (%)</td>
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<td>-------------------------------------------------------------------------------</td>
<td>--------------</td>
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<td>Tablet</td>
<td>7 (47)</td>
</tr>
<tr>
<td>Personal laptop (not for work purposes)</td>
<td>11 (73)</td>
</tr>
<tr>
<td>Access to Wi-Fi at home</td>
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</tr>
<tr>
<td>Yes</td>
<td>13 (87)</td>
</tr>
<tr>
<td>No</td>
<td>2 (13)</td>
</tr>
</tbody>
</table>

aMean age 65.8, SD 6 years.

bAn affordable housing rental option for Singaporeans with low income [31].

cHDB: Housing and Development Board.

dA public housing type in Singapore, which is affordable and can be easily purchased by the average Singaporean as they are subsidized by the government and are offered with housing grants (4-room HDB flat: 3 bedrooms and 1 living room; 5-room HDB flat: 4 bedrooms and 1 living room) [32].

eA dwelling house with its own land title that forms part of a row of at least 3 dwelling houses abutting the common boundary party walls [33].

fA single-family duplex dwelling house that shares a common wall with the next house [34].

gAn apartment that is part of a development not managed by the HDB, owned by unit owners who share common areas and facilities with other unit owners within the development [35].

hA strata-titled property, with comparable designs and facilities to other condominiums [35].

Consequences of HSB in the Aging Context

Overview

Our interviews identified five main consequences of HSB, namely, (1) health information seeking, (2) health maintenance, (3) early diagnosis and complication control, (4) responses to symptoms, and (5) health service use.

Health Information Seeking

Health Education Participation

In total, 87% (13/15) of the participants have attended government, hospital, university, and other community health educational sessions or self-read the health information on mobile health (mHealth) apps, through which they could gain knowledge about various health topics:

I’m a volunteer with HPB, and we do conduct health talks. I’m interested in that and I’m still active with it. They have [the] War of Diabetes, and some [talks] focus on exercise and nutrition. [Participant 2]

I attended the wellness and health [talk] held by Boon Lay CC last year on the 26th of December, the day after Christmas. I registered myself there to study health and wellness and they taught me to download some of the apps such as 365 [the Healthy 365 app]. I attended the health coaching course offered by NTU [Nanyang Technological University]. [Participant 13]

I attended one group education in KTPH [the Khoo Teck Puat Hospital]. [Participant 15]

Overall, 5 factors were identified to have an impact on the preference and judgment of health education, namely, the instructors’ qualification, instructors’ language or terminologies, usefulness and relevance of the content, cost, and personal interest. Sample responses are summarized in Multimedia Appendix 3.

Health Information Searching and Sharing

In total, 87% (13/15) of the participants actively searched for health information, and the most common information sources were the web (eg, Google, Wiki, and forums), mHealth apps, social networks (family members and friend groups), health professionals, and their fields of medicine expertise:

Yes, I will check online or ask friends...I [also] use the HealthHub app...I found it very useful. And it does have family program[s] and health tips that I can go to find out more. [Participant 2]

Normally my friends and I will share health information in [the] WhatsApp group, we are in a retiree group. [Participant 6]

I collect health information from the doctor. [Participant 8]

Actually, I know all these investigations [that have been] done quite well because I worked in the hospital before, so I know all these tests, what they are for, and you must take some medication regularly. [Participant 10]

Health Information Evaluation

Participants adopted multiple methods to evaluate the credibility of the health information: (1) relying solely on official sources, (2) seeking verification from health professionals, (3) checking the credibility of information sources, (4) searching for scientific evidence, (5) gathering information from individuals with similar experiences, and (6) self-experiment. Sample responses are summarized in Multimedia Appendix 4.

Participants shared that their health information searching and participation in health education could empower themselves with health-related knowledge. They have gained a deep understanding of well-being and diseases, and that has led them to better awareness of their bodies and a positive shift in their health behavior:

I become aware of the diseases, and for example, I know that if I eat a lot of fatty stuff, my cholesterol...
will be affected, thereby when I choose the food I will read the label, so in my daily life I choose food and all those, I become educated. After I know all the knowledge but don’t practice in my daily life, it’s like zi jǐ zhāo sǐ [killing myself] right? [Participant 5]

We all understand that exercise is good for our health which I’m doing every day. Moderation is the key for any food you take, and I never take excessive [but] just moderate and take what I need. And also need to keep your mental health good, and the more you use your brain the more you can keep your brain; [if] you don’t use your brain, you may get dementia. Human beings need group activities like we walk together, and we go to the SACs [Senior Activity Centers] to talk to the elderly. And this way you need friends to be able to listen to your problems, and you don’t separate from the society, and that might lead to some mental problems like depression and dementia. [Participant 6]

**Health Maintenance**

All participants (15/15, 100%) shared that they have been pursuing healthy lifestyles and strengthening social connections to maintain their physical, mental, and social capacities:

- *Enough sleep, proper diet, [and] regular exercise [help me maintain my health]. [I’m] getting myself active in daily activities, just to keep me mentally and physically engaged.* [Participant 3]
- *I have several groups like my line dancing group, volunteering groups of a few institutions...These people really keep me mentally on the spot.* [Participant 5]

**Early Diagnosis and Complication Control**

**Health Screening and Follow-up Care**

All participants (15/15, 100%) have been undergoing regular health screenings and follow-up care, with frequency varying from several months to several years, contingent on the purposes (eg, disease screening and chronic condition monitoring):

- *Once every three or four months I go for my health screening, once a year I get my flu injection, [and] once a year I also go [for] ultrasounds on my lungs, chest, and prostate.* [Participant 8]

**Self-measurement of Vital Signs**

Vital signs are noninvasive objective measures of a person’s physiological function using simple equipment, such as pulse, temperature, blood pressure, and respiratory rate [36]. They could serve as a basic means to communicate about a person’s health status and keep track of both acute and chronic conditions [36]. In our study, only 7% (1/15) of the participants reverently measured his vitals at home and 60% (9/15) of the participants determined when to perform self-measurement based on the bodily symptoms or daily activities, whereas the rest did not practice self-measurement. Overall, four reasons were reported: (1) self-perceived good health, (2) inability to schedule, (3) lack of necessary equipment at hand, and (4) difficulty in obtaining accurate measurements. Sample responses are summarized in Multimedia Appendix 5.

**Self-perceived Health and Responses to Symptoms**

Despite the impacts of the COVID-19 pandemic on the participants’ physical, mental, and social well-being (as seen in Multimedia Appendix 6), all participants (15/15, 100%) perceived their health to be good to excellent and stated that they rarely fell sick. In the event of any symptoms, three different actions were taken: (1) self-treatment; (2) seeking prompt professional medical attention; and (3) undergoing a logical process from self-treatment to seeking professional medical attention, depending on the severity of symptoms. Sample responses are summarized in Multimedia Appendix 7.

**Health Service Use**

**Satisfaction With the Living Environment**

All participants (15/15, 100%) were satisfied with their living and surrounding environments. They could easily access recreational spaces (eg, fitness facilities, parks and open spaces, and walking and cycling paths), amenities (eg, grocery stores and health stores such as Guardian), public transportation (eg, bus stops and Mass Rapid Transit stations), and health care services (eg, outpatient polyclinics, private general practitioners [GPs], and hospitals), and this could make their life more convenient and healthy:

- *My house is very accessible, and during COVID time we have walked to all the connectors, and we can also walk around within the whole estate.* [Participant 7]
- *Good! It’s within [a] 10-20 mins walk to the facilities. Every day I make the trip down to the mall with a library there and use the shopping mall and polyclinic. I also walk, it’s like a form of exercise.* [Participant 10]

**Access—Cost**

All participants (15/15, 100%) shared that various government subsidies, such as the Community Health Assist Scheme, Merdeka Generation Package, and Pioneer Generation Package, enabled them to access affordable medical services:

- *We have the CHAS [Community Health Assist Scheme] cards, we have the Pioneer Generation card, so the charge is minimal, I will say [it is] very affordable...[The health screening is] very affordable, there are two layers of subsidies.* [Participant 10]

**Access—Waiting Time**

Most participants (11/15, 73%) reported that physicians’ consultations were fast, but the waiting time could be hours, even with an appointment:

- *The consultation is very fast, but the waiting time to see the doctors can take hours.* [Participant 1]
- *My appointment was set at 11:30 [am] in the morning [after a long weekend], but I did not see the doctor until 4:30 pm, that is unusual, and even the doctor...
said “today is unusual”. The consultations are usually very fast. [Participant 6]

Interaction—Communication With Health Professionals
Our participants reported a general desire to engage in more health-related discussions with their physicians, but the physician-patient communications varied with health professionals and could affect patients’ emotions:

Very good because we have been seeing this family doctor for many many years, so we are very comfortable. The communication is very good. [Participant 7]

I hardly see GP so I cannot comment on it. I only can comment [on] those doctors that I have seen in [the] polyclinic. These doctors keep on changing, it’s not a specific doctor. I find it poor because sometimes I do feel that they are just doing their job only. Poor in the sense that I feel that sometimes they just do their job to move you away because they have so many patients. But sometimes there are some pretty good doctors, and they do try to explain, so I cannot generalize that. I will see 2 extremes: when I meet good doctors, I’m very happy, but when I meet these so-called poor doctors who are not with the patient, then I will say “okay lah I go polyclinic what do you expect.” [Participant 9]

Technology Use in Older Adults’ Health Seeking
We explored the use of technologies in each consequence of the older adults’ HSB (Figure 2) and extracted 4 main themes: theme 1—the most widely used digital technologies among the older population are mHealth apps and wearable devices with associated wellness programs launched by government agencies and local companies, and these technologies have the potential to enhance health communication, promote health maintenance, and increase access to health services; theme 2—information communication technologies (ICTs) and social media, although not primarily designed for health purposes, play a substantial role in easing the process of seeking health information and managing symptoms; theme 3—although the outbreak of the COVID-19 pandemic has resulted in some alterations to older adults’ well-being, it has catalyzed the adoption of telehealth as a complement to access health care services; and theme 4—older adults have different considerations when selecting technologies to facilitate their health seeking and fulfill their health needs.

Theme 1—The Most Widely Used Digital Technologies in Health Seeking Among the Older Population

Health Communication
Health communication leverages technological innovations, such as mass media and multimedia to spread health information, enhance public understanding of health, educate the public about health concerns, and keep critical health issues on the public agenda [37]. Our participants shared that they were able to locate information about health programs and health tips through mHealth apps developed by the government:

I use the HealthHub app...I found it very useful. And it does have family programs[s] and health tips that I can go to find out more. [Participant 2]
Health Maintenance

Most of the participants (10/15, 67%) reported using various mHealth apps and wearable fitness trackers, launched by either government or local companies, to track their daily physical activities and stay motivated toward achieving their health goals. They could also receive attractive incentives from the associated health campaigns:

I use it [Healthy 365 app] for step tracking. I participated [in the] National Steps Challenge as this is free money...I call it preventive medicine because they pay you to lose weight. [Participant 9]
I use [the] SingTel StepUp program also, every month I can redeem at least 2 free Gigabytes for myself. [Participant 14]

Overcoming Challenges in Health Service Use

Although most of the participants (11/15, 73%) expressed frustration with the long waiting time to see physicians, a few of them shared that mHealth apps such as the HealthHub app could offer them a platform to receive real-time updates about the waiting time and manage their nonurgent appointment bookings:

With the appointment on the HealthHub app, I can check how many more patients [are] ahead, then I hang out outside. It doesn’t bother me if I have to wait very long. [Participant 5]
I was using HealthHub to check the information about my appointment. [Participant 14]

Besides managing appointments, participants said that they could also view test results and health reports on the mHealth apps:

I go there [the HealthHub app] to do [medical appointment] booking, checking my appointment, and checking my blood test results. [Participant 9]

Tele-Education

Several participants (5/15, 33%) shared that some of their regular health education sessions were adapted to a web-based format via Zoom amid the COVID-19 pandemic, and this allowed them to continue their learning journey with tele-education:

We had quite a number of Zoom lectures from HPB [the Health Promotion Board]. [Participant 1]
365 [Cancer Prevention Society] sometimes has little talks about nutrition, I do go in and listen on Zoom. [Participant 9]

Remote Health Tests

The COVID-19 pandemic did not eradicate the participants’ regular health screenings, but the initial lockdown has caused some delays. Some participants chose to postpone their health screening to prevent possible infection and were offered self-tests as a substitute:

I didn’t go for the blood test as my husband [who is a doctor] told me not to go. But I still did one free test which they sent to me, I collected the specimen and sent it back to them. [Participant 5]
**Theme 4—Considerations When Selecting Technologies to Facilitate Health Seeking**

When asked about how to select technologies, eight factors were reported by the participants, namely, (1) perceived usefulness, (2) comprehensiveness of features, (3) perceived ease of use, (4) performance and quality, (5) recommendation by the social network, (6) cost, (7) rewards, and (8) credibility. Sample responses are summarized in Multimedia Appendix 8.

**Textbox 1.** The 4 proposed archetypes.

- **Archetype 1**
  - Inactive in health seeking
- **Archetype 2**
  - Proactive in health seeking but hesitant to adopt technologies
- **Archetype 3**
  - Proactive in health seeking and receptive to technologies but facing challenges in accessing or using technologies
- **Archetype 4**
  - Proactive in health seeking, receptive to technologies, and able to access and use technologies

**Discussion**

**Principal Findings**

This study expanded upon the literature by adopting the multidimensional model by Poortaghi et al [30] to explore the HSB of older adults in the Singapore community. Unlike previous studies that only focused on health system use and illness responses, our study explored older adults’ health-seeking practices with a comprehensive approach, including health information seeking, health maintenance, early diagnosis and complication control, responses to symptoms, and access to and interaction with health care services. We also examined older adults’ technology use and considerations for technology selection, and our results offered a different perspective from a previous qualitative study in Singapore, which found that older adults’ HSB was technology independent [38]. Our findings suggested that technologies have been seamlessly integrated into older adults’ health-seeking activities and have a promising capability of encouraging proactive HSB.

**Archetypes**

The participants in our study exhibited a relatively consistent response pattern. However, our results, coupled with insights from our participants’ observations within their social networks, have led us to propose 4 archetypes. These archetypes were designed based on factors such as the activeness level of their HSB, access to technologies, willingness to adopt technologies, and capability to use technologies (Textbox 1).

**Consequences of HSB in the Aging Context**

We identified a total of 5 major consequences of HSB, namely health information seeking, health maintenance, early diagnosis and complication control, responses to symptoms, and health service access and interaction, which are consistent with the model by Poortaghi et al [30]. Although we made an effort to recruit participants with varying sociodemographic and socioeconomic characteristics and observed relatively consistent patterns, the exploratory nature and limited sample size of qualitative research may restrict the generalizability of our findings. Future studies could expand on our study by incorporating the antecedents in the model by Poortaghi et al [30] and evaluating the impact of social, cultural, economic, and health-related factors on HSB, to uncover the unfulfilled needs of the older population.

**Technology Use in Older Adults’ Health Seeking**

A key discovery was the older adults’ wide engagement with technologies and associated health campaigns launched by the government and local companies. Supporting the findings by Low et al [38], most of our participants (10/15, 67%) were motivated to use wearable fitness trackers together with mHealth apps to keep track of their physical activities. These technologies could provide users with real-time feedback and motivate them to achieve the predetermined lifestyle goals [39]. Moreover, the financial incentives offered by these initiatives seemed to be an important motivator for older people to use such technologies and encourage positive changes and discourage negative ones in health behavior [40]. Future studies could further investigate the extent to which technology-driven behavior change techniques such as incentive schemes can alter users’ behavior and improve their health outcomes. It would also be valuable to explore how such techniques can be integrated with policy tools to facilitate sustainable behavior change.

Technologies offer a solution to overcome the challenges in health service use and interaction. Although all our participants (15/15, 100%) were satisfied with their living and surrounding environments, were able to easily access primary care, and could enjoy affordable medical services through various government subsidies, they pointed out 2 challenges during the interaction with the current health systems. Similar to a theme in the findings by Lee et al [5], many of our participants (11/15, 73%) also shared their experience of waiting several hours for just a few-minute consultation, particularly after public holidays and during the COVID-19 pandemic. In addition, they also encountered communication barriers and even felt discouraged from engaging in further communication as they felt pushed...
away by their health professionals. These might be attributed to a shortage of health professionals in the country, as reported by the Ministry of Health that the physician-to-population ratio was 1:399 and there were only 2.5 physicians per 1000 population in 2019 [41]. In addition to incorporating self-service medical booths [42], the use of digital technologies such as the machine learning–based solution being developed by the Singapore National Eye Center, called Appointment Scheduling Optimizer, could reduce patients’ waiting time [43]. Telehealth, which has the potential to reduce expenses and time spent on traveling and waiting [44], might offer another viable solution, but future studies are needed to further reaffirm the acceptability, effectiveness, and cost benefits of telehealth services.

ICT and social media expand people’s alternatives in searching for health-related information; however, they are not tailored to health intentions and cannot alleviate, diagnose, or cure diseases. In contrast to the findings by Lin et al [45] that only a small portion of the participants searched for health information on the web using their mobile phone, a high percentage of older participants in our study used their smartphones for searching and sharing health information, via web-based resources, social media, mHealth apps, and messaging through social network communication tools. This difference may stem from the improved accessibility and easy sharing of information through mobile phones in recent years. Some of the government initiatives have also begun to harness these platforms, such as HPB’s posting of health-related videos on YouTube for health promotion [46] and the launch of the official COVID-19 channels on Telegram and WhatsApp to broadcast news updates, deliver important announcements, and reduce the spread of misinformation during the COVID-19 pandemic [47]. An unexpected result was that almost all participants (14/15, 93%) made an effort to question and assess the credibility of the health information. They exhibited skepticism toward the health information encountered and used various means to verify its credibility. Our findings suggested that technologies have shaped health information seeking as a collective and collaborative effort—people first gather information; next, verify and circulate it through their social network; and then, apply it in their daily practice and provide feedback. Through this cyclic seeking-verifying-sharing-applying-feedback process, they can reaffirm the credibility and effectiveness of the information through firsthand experience.

Although the COVID-19 pandemic has brought some alterations to older people’s well-being and disruptions to their lifestyle practices, it also catalyzed technological innovation and adoption. For example, telehealth, although not a novel concept [48,49], gained increasing attention amid the COVID-19 pandemic [50]. Our participants shared that different telehealth modalities could enable them to continue their access to health care services and health education. Future studies could further evaluate the role of telehealth in aging care.

Implications for Practice
This section serves as the last consequence in the HSB model by Poortaghi et al [30]—*design and implement needed services.*

Health Communication and Promotion
According to our findings, ICT and social media appeared to be promising channels for obtaining and exchanging health information. Previous studies also reported that many older citizens in the Singapore community are not resistant to technologies, and they spent more time on smartphones watching dramas, playing games, and chatting on messaging platforms [51,52]. Leveraging these platforms and launching eHealth communication and promotion campaigns could be a viable strategy to increase health awareness and encourage participation among the older population.

Health Education
Our participants shared that the overriding factors affecting their preference and evaluation of health education are the qualifications of and language used by the health instructors, usefulness and relevance of the content, cost, and personal interest. Although there is no *one-size-fits-all* solution, future health education programs could take these factors into consideration.

Technology Design, Improvement, and Implementation
Participants shared various factors in technology selection, but the results may be limited by the types of such technologies that they have used before. In contrast, this also implies that older adults might be granted access to a wider variety of digital technologies. Besides perceived usefulness, perceived ease of use, and financial cost found by Lin et al [45], our participants also shared that the comprehensiveness of features, quality of performance, recommendations by their social network, rewards, and credibility are the other overriding considerations. Taking these factors into consideration would be useful not only for technology developers when enhancing current technologies or creating novel ones to promote better user-centered designs but also for policy makers in the process of digital transformation and building the *smart nation*.

Clinical or Community-Based Telemonitoring Services to Support Older Adults’ Self-measurement Practice
A possible gap we identified in the participants’ HSB was a lack of self-measurement of their vital, especially for those with chronic conditions. Single-point vital sign measurements have shown to be less sensitive in detecting disease processes as a result of the diverse but individual age-related physiological changes and comorbidities, whereas successive or serial measurements may enhance the sensitivity in detecting disease processes, especially when viewed in conjunction with individualized reference ranges [36]. In Singapore, some polyclinics have introduced telemonitoring services for patients with chronic health conditions, and such services have been well accepted [53,54]. Patients who rely solely on physical examinations, who do not own a personal device, and who are occupied with daily chores can get the necessary devices and benefit from such services for chronic disease management, as prompt measurements can be taken beyond the health care setting. Besides clinical approaches, community-based initiatives can be used to make technology more accessible to the public and aid those who have difficulty in obtaining accurate measurements. For example, telemonitoring kiosks with trained
health ambassadors in the community can be set up to provide users with health tips and gather data to help health professionals make better decisions. By implementing these ground-up strategies, older individuals can enjoy better access to quality health care services and technologies; reduce expenses associated with travel and medical equipment purchases; take a more proactive role in managing their health; and ultimately, reduce health disparities. Future studies could further investigate the effectiveness of telemonitoring in detecting diseases and reducing complications, hospital readmissions, and mortality rates in aging care.

**Possible Solutions to Facilitate the Health Seeking of the Proposed Archetypes**

It is important to note that although technologies play a promising role in assisting older people’s health seeking, they are not mandatory. People may have various reasons for using or not using technologies; therefore, it is crucial to uncover their specific health needs and ensure that no one is forced to use technologies or left behind in digital inclusion.

**Archetype 1—Inactive in Health Seeking**

For archetype 1, the priority might be identifying older people’s unfulfilled needs and seeking tangible resources from both health care and community settings. Some possible strategies include educating them about the significance of proactive HSB through public health campaigns, providing regular updates about their health status, and ensuring that they are not left behind in digital inclusion.

**Archetype 2—Proactive in Health Seeking but Hesitant to Adopt Technologies**

For archetype 2, it might be helpful to work with health professionals and assess the need for incorporating technologies in their health seeking. Through this joint effort, they can determine the most suitable solutions to meet their specific needs. At the same time, they can be invited to attend health events or participate in awareness campaigns to gain firsthand experience regarding the benefits of technologies and make informed decisions.

**Archetype 3—Proactive in Health Seeking and Receptive to Technologies but Facing Challenges in Either Accessing or Using Technologies**

For archetype 3, the focus could be on lowering the barriers to using technologies. Some possible strategies might be introducing simple technologies in small steps, offering assistance and support to build people’s technology skills (eg, the Senior Go Digital program [55]), encouraging social engagement and creating a supportive community, and improving both user-friendliness and accessibility of technologies for the older population.

**Archetype 4—Proactive in Health Seeking, Receptive to Technologies, and Able to Access and Use Technologies**

Archetype 4 might be the most suitable candidate for technology use and require the least amount of support. The focus could be on developing innovative technologies and policy solutions to sustain and enhance their HSB.

**Strengths, Limitations, and Future Studies**

This study had several strengths. Conceptually, we extended the literature by adopting a multidimensional model and assessed the older adults’ HSB using a more comprehensive approach, and our findings further reiterated this model. Methodologically, we adopted multiple recruitment strategies to reduce selection bias, and we managed to get insights from older adults with varying sociodemographic and socioeconomic characteristics in Singapore. Despite these strengths, we acknowledge that our study also had some limitations. First, most participants (13/15, 87%) were Chinese, which might be because of the inclusion of only English and Mandarin speakers, considering the researchers’ language proficiency. Future studies could be extended to Malay, Tamil, and Chinese dialect speakers. Second, owing to the COVID-19 pandemic restrictions, the main method of participant recruitment and contact was through social media and WhatsApp, which could have resulted in a possible bias toward individuals who were more technologically advanced and had better access to technologies. Future studies should attempt to reach out to individuals who are digitally illiterate or homebound. Finally, this was an exploratory qualitative study with a limited sample size, and the choice of the individual as the unit of analysis to understand group phenomena may overlook certain fine points and variations among individuals. Large-scale quantitative or mixed methods studies could further investigate the impact of social, cultural, economic, and health factors (the antecedents in the model by Poortaghi et al [30]) on older adults’ HSB and how technologies can address these inequalities.

**Conclusions**

In conclusion, we have extended the literature and investigated older adults’ HSB and associated technology use with a more comprehensive approach. Unlike the commonly held belief that older adults resist technologies and lack technological proficiency, our results showed that technologies could play a promising role in facilitating older adults’ health seeking. Our findings have implications for the design and implementation of health services and policies.

**Acknowledgments**

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Data Availability
The data sets generated and analyzed during this study are available from the corresponding author upon reasonable request.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Semistructured interview guide.
[DOCX File, 16 KB - aging_v61e43709_app1.docx ]

Multimedia Appendix 2
Detailed participants' characteristics.
[DOCX File, 20 KB - aging_v61e43709_app2.docx ]

Multimedia Appendix 3
Sample responses regarding the preference and evaluation of health education.
[DOCX File, 15 KB - aging_v61e43709_app3.docx ]

Multimedia Appendix 4
Sample responses regarding evaluating the reliability of information sources.
[DOCX File, 16 KB - aging_v61e43709_app4.docx ]

Multimedia Appendix 5
Sample responses regarding self-measurement.
[DOCX File, 16 KB - aging_v61e43709_app5.docx ]

Multimedia Appendix 6
Sample responses regarding the impact of the COVID-19 pandemic on older people’s perceived health.
[DOCX File, 16 KB - aging_v61e43709_app6.docx ]

Multimedia Appendix 7
Sample responses regarding health service use.
[DOCX File, 14 KB - aging_v61e43709_app7.docx ]

Multimedia Appendix 8
Sample responses regarding the choice of health technologies.
[DOCX File, 15 KB - aging_v61e43709_app8.docx ]

References

https://aging.jmir.org/2023/1/e43709

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JMIR Aging 2023 | vol. 6 | e43709 | p.317
(page number not for citation purposes)

8. Constitution. World Health Organization. URL: https://www.who.int/about/governance/constitution [accessed 2022-08-12]


44. Zhang Y, Leuk JSP, Teo WP. Domains, Feasibility, Effectiveness, Cost, and Acceptability of Telehealth in Aging Care: Scoping Review of Systematic Reviews. JMIR Aging 2023 Apr 18;6:e40460 [FREE Full text] [doi: 10.2196/40460] [Medline: 37071459]


46. hpbsg. YouTube. URL: https://www.youtube.com/user/HPBsg/videos?app=desktop [accessed 2022-03-13]


52. Singapore RN. Seniors are spending too much time on their smartphones which can spell trouble. National University of Singapore. URL: https://fass.nus.edu.sg/srn/2021/10/07/seniors-are-spending-too-much-time-on-their-smartphones-which-can-spell-trouble/ [accessed 2022-03-13]


Abbreviations

COREQ: Consolidated Criteria for Reporting Qualitative Research
GP: general practitioner
HSB: health-seeking behavior
ICT: information communication technology
mHealth: mobile health
SMM: safety management measure

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Review

Older Adults and New Technology: Mapping Review of the Factors Associated With Older Adults’ Intention to Adopt Digital Technologies

Tanja Schroeder1,2*, BA, MA; Laura Dodds3, MPH; Andrew Georgiou1, PhD; Heiko Gewald2, BSc, MBA, EMBSc, PhD; Joyce Siette1,3*, B Psych, PhD

1Centre for Health Systems and Safety Research, Australian Institute of Health Innovation, Macquarie University, Macquarie Park, Australia
2Centre for Research on Service Sciences (CROSS), Neu-Ulm University, Neu-Ulm, Germany
3The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Westmead, Australia

*these authors contributed equally

Corresponding Author:
Joyce Siette, B Psych, PhD
The MARCS Institute for Brain, Behaviour and Development
Western Sydney University
Westmead Innovation Quarter
160 Hawkesbury Road
Westmead, 2145
Australia
Phone: 61 2 9772 6648
Email: joyce.siette@westernsydney.edu.au

Abstract

Background: Ongoing advancements in digital solutions support older adults’ healthy aging and well-being. However, a unified synthesis of sociodemographic, cognitive, attitudinal, emotional, and environmental factors that influence older adults’ intention to use these new digital technologies is still lacking. Understanding the salient factors that influence older adults’ intention to use digital technologies will help to ensure that technology is developed appropriately and contextually. This understanding is also likely to contribute to developing technology acceptance models specifically for the aging generation, by reorganizing principles and constructing objectivity criteria for future research studies.

Objective: This review aims to identify the key factors associated with older adults’ intention to use digital technologies and to provide a comprehensive conceptual framework to describe the relationships between these key factors and older adults’ intention to use digital technologies.

Methods: A mapping review was conducted using 9 databases from inception to November 2022. Articles were selected for review if they had an evaluative component of older adults’ intention to use digital technologies. Three researchers independently reviewed the articles and extracted the data. Data synthesis was performed via narrative review and quality appraisal was measured using 3 different tools based on each article’s study design.

Results: We identified a total of 59 articles investigating older adults’ intention to use digital technologies. The majority (40/59, 68%) of articles did not use an existing framework or model for technology acceptance. Studies mostly adopted a quantitative research design (27/59, 46%). We found 119 unique factors reported to influence older adults’ intention to use digital technologies. These were categorized into 6 distinct themes: Demographics and Health Status, Emotional Awareness and Needs, Knowledge and Perception, Motivation, Social Influencers, and Technology Functional Features.

Conclusions: Given the importance of global demographic change toward an aging society, there is surprisingly limited research on the factors that influence older adults’ intention to use digital technologies. Our identification of the key factors across different types of digital technology and models supports the future integration of a comprehensive perspective encompassing environmental, psychological, and social determinants for older adults’ intention to use digital technologies.

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KEYWORDS
technology adoption; digital technology; older adults; seniors; intention to use digital technologies

Introduction

Technological innovation and the constantly increasing use of the internet are creating unique opportunities to assist older adults’ (here defined as persons with a physical age of 65 years and above) health and well-being [1]. There is growing evidence of the benefits that older adults experience when they use digital technologies. These include improvements in their cognitive, social, and emotional well-being [2]. Technologies such as computers, the internet, and mobile phone apps have been found to be effective tools in managing health conditions and supporting well-being [3]. Although older adults’ adoption rates of technology have traditionally been low, they are nowadays increasing and the gap toward the younger generations is closing significantly [4]. In this era of increased global aging, the World Health Organization estimates that by 2030, 1 in 6 people in the world will be aged 60 years or over [5], and that it is necessary that technological developments become more age-friendly and usable by older adults. However, the factors influencing older adults’ intention to use digital technologies are not yet fully understood.

The information systems discipline has developed various models of technology acceptance to understand the factors leading to the acceptance, adoption, use, and continuous use of technology. Among the most widely used theoretical frameworks are the Technology Acceptance Model (TAM) [6] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [7], which have been developed based on broadly defined adult populations with expansive age brackets [8].

Formulated by Davis [6], the TAM describes individuals’ acceptance of technologies [9] and has been applied to a wide variety of contexts including the health care sector [10]. The TAM suggests that perceived usefulness (i.e., whether the users perceive the technology as helpful to achieve the intended purpose) and perceived ease of use (i.e., whether the users perceive the technology to be easy to use for them) explain an individuals’ intention to use digital technology [6,11]. Based on the Theory of Reasoned Action [12], intention is regarded as a powerful predictor of actual use. However, the main points of criticism for the TAM are that its measurement relies on self-reported perceptions and that the dependent variable is behavioral intention, not the actual use of a technology [13]. Furthermore, the model does not consider factors including age and education, external variables which could influence willingness to use technology [14]. As such, more recent model developments have taken place.

The UTAUT model [7], developed by Venkatesh et al [7], combines and integrates 8 theories to explain human behavior with respect to technology adoption. It identifies 4 major constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions), along with 4 moderators (age, gender, experience, and voluntariness) to predict individuals’ use of technology [7,15]. In 2012, the UTAUT model was further developed into the UTAUT 2 model by Venkatesh et al [8]. The authors extracted factors for the consumer context and extended it by incorporating another 3 factors, namely, hedonic motivation, price value, and habit, which improved the prediction of behavioral intention to use behavior. The UTAUT 2 includes 3 moderators: age, gender, and experience [8]. The TAM and UTAUT received enormous attention in academia and practice, and probably belong to the most tested, adapted, and extended models in information systems research. However, both models share the same weakness that they were not developed with consideration of different application areas, which can be beneficial or detrimental. Furthermore, they do not incorporate the fact that technology acceptance may change over time [11].

In 2000, the original TAM was expanded by Venkatesh and Davis [16] with some elements and republished as TAM2, with further revisions made in 2008 to create TAM3 [17]. In TAM2, the input variables were differentiated into the groups of social influence and cognitive processes. TAM3 is based on the acceptance variables of the original TAM (i.e., perceived usefulness, perceived ease of use, and intention to use) and TAM2 (i.e., experience, voluntariness, subjective norm, image, workplace relevance, quality of outcome, and presentable results). This model is supplemented by the subcategories anchor and adjustment, which include computer self-efficacy, perception of external control, computer anxiety and computer playfulness, as well as perceived enjoyment and objective usability. The Senior Technology Acceptance Model [18] also describes a further development of the TAM and captures the context of the older mobile phone user. Here, intention to use is primarily determined by perceived usefulness and social influence (i.e., children urging their parents to use the phone). The variables are social influence, intention to use, perceived usefulness, facilitating conditions, experimentation and exploration, confirmed usefulness, ease of learning and use, and actual use.

However, despite these adjustments, within gerontology and aging research fields, a widespread deficiency of the existing technology acceptance models is the neglect of biophysical factors (e.g., cognitive and physical decline) and psychosocial factors (e.g., social isolation and fear of illness) [19]. As such, extant theoretical models of technology acceptance are not fully applicable to members of the aging population [20].

This systematic mapping review is set to capture the diverse literature available on this topic and provide in-depth insights into overarching concepts to further advance this field. Furthermore, a framework that incorporates the most up-to-date evidence of how the key factors interact and their impact on older adults’ behavioral intentions is yet to be produced. By tracking the flow of information through publications using a mapping review, linkages between core concepts related to the intended use of technology across disciplines can be identified [21,22].

This mapping review thus provides a synthesis of current research on older adults’ intention to use digital technology and...
the corresponding salient factors. Our objective was 2-fold: (1) to identify the key factors associated with older adults’ intention to use digital technologies, and (2) to provide a comprehensive conceptual framework to describe the relationships between these key factors and older adults’ intention to use digital technologies. These findings will provide directions for further research addressing the specific user group of older adults.

Methods
Study Design
A systematic mapping review was used to identify the published original articles related to intention to use digital technology by older adults. The review protocol was registered with PROSPERO (International Prospective Register of Systematic Reviews; registration number CRD42022329705) and the selection process is outlined in Figure 1.

Search Strategy and Study Selection
A search was conducted from inception to November 15, 2022, in 9 databases including CINAHL Complete, MEDLINE Complete, PubMed, Embase, Scopus, AIS Electronic Library, IEEE Xplore, AIS Senior Scholar Basket Journals, and ACM digital library: Databases (n=3598). Broad keywords used were the following combination of 4 groups of keywords: older adults (e.g., aged, older, senior, elderly) AND technology factor (e.g., acceptance, adoption, use, adherence, rejection) AND influence (e.g., behaviour, psychology, motivation) AND technology type (e.g., technology, computers, eHealth, system, assistive technology, robotics, smart home, gerontechnology, telemonitoring). The full search strategy was updated on November 15, 2022 and is provided in Multimedia Appendix 1.

Inclusion Criteria
Original and peer-reviewed journal publications and conference proceedings written in English and using qualitative, quantitative, or mixed methods research were included. Studies had to include participants who were older adults (aged 65 years or older) and had an evaluative component of either
demographic, cognitive, physical, or emotional factors that influenced the intention to use or actual use of digital technology.

All titles and abstracts of the identified studies were subsequently screened for eligibility by 3 reviewers (JS, LD, and TS) independently, applying the following inclusion criteria: (1) original and peer-reviewed research written in English with either a qualitative, quantitative, or mixed methods approach; (2) participants were older adults aged 65 years or more; and (3) research was aimed at investigating factors that influence the intention to use or the actual use of digital technologies for older adults. The 3 researchers then conferred to resolve any discrepancies on eligibility, and if an agreement could not be made, a fourth reviewer (AG) was consulted. The full text of the remaining studies was then checked and those that did not meet all inclusion criteria were excluded. The references of the selected studies were hand searched for other potential studies (snowballing method; Figure 1).

Assessment of Methodological Quality
Methodological quality was assessed using the Critical Appraisal Skills Program, the Cochrane Risk of Bias, and the Mixed Methods Appraisal Tool (MMAT) [23] which, in addition to specific criteria for qualitative and quantitative research, also contains specific criteria on the relevance of the use of a mixed methods design and the integration of different types of results. The researchers assessed the methodological quality of all included studies independently, followed by a discussion of their findings to determine the final rating for each study. It was decided not to exclude articles based on quality assessment because there is little empirical evidence on which to base exclusion decisions in mixed studies systematic reviews [23-25]. Instead, it was decided to report on the quality of the reviewed articles and to apply independent triangulation: at least two quality criteria had to be present in studies to be included in the results.

Data Extraction and Synthesis
As included articles ranged from qualitative to quantitative methods (or a combination of both), data extraction forms for both design types were designed. For qualitative articles and qualitative information from mixed methods articles, acceptance factors were coded and entered. For quantitative articles and quantitative information from mixed methods articles, variable/factor name and level of significance were entered into the data extraction form. Two authors (TS and JS) reached consensus on the data extraction form for each article.

Thematic synthesis [25] was used to synthesize qualitative data on technology use and intention to use factors. Multiple sessions in the research team were then held to group factors derived from articles into descriptive themes for acceptance in post-technology implementation. JS, LD, and TS each created a conceptual model of the relationships between themes, and through iterative discussions developed 1 final model. Factors derived from qualitative articles and mixed methods articles were compared with factors identified in quantitative articles. This allowed us to highlight which factors were statistically tested in quantitative research. Quantitative articles were summarized thematically. For this purpose, all factors examined were first extracted and compiled. We summarized thematically related factors into individual group categories to create a better overview. Cluster analysis was used as an explorative method to establish the group categories and to classify the individual factors by purpose and type. Subsequently, we also added the factors examined in the qualitative articles.

Results
Overview
The study characteristics of the 59 articles analyzed are shown in Table 1. Most articles (36/59, 61%) were written in the last 5 years, published in the United States (25/59, 42%), and conducted in a community-dwelling setting (23/59, 39%), with 39,153 older adults sampled (sample size ranged from 5 to 14,798).
Table 1. Summary of the included articles.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Country</th>
<th>Study design</th>
<th>Setting</th>
<th>Sample size, n</th>
<th>Sample mean age (years)</th>
<th>Proportion of female, %</th>
<th>Technology type</th>
<th>Technology subtype</th>
<th>Purpose</th>
<th>Social interaction</th>
<th>Independence</th>
<th>Model used</th>
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<td>Franks and Beckmann</td>
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<td>60</td>
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<td>—</td>
<td>✓п</td>
<td></td>
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<tr>
<td>Billip Heyn</td>
<td>United States</td>
<td>E[^c]</td>
<td>Home care</td>
<td>40</td>
<td>73</td>
<td>82</td>
<td>Everyday technologies</td>
<td>Computer</td>
<td>—</td>
<td>✓</td>
<td>✓п</td>
<td></td>
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<tr>
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<td>15</td>
<td>79.5</td>
<td>—</td>
<td>Everyday technologies</td>
<td>A computer game</td>
<td>—</td>
<td>—</td>
<td>✓п</td>
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<td>Client-server computer application</td>
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<td>✓п</td>
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<td>✓п</td>
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<td>Remote or assistive care technologies</td>
<td>Smart home device</td>
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<td>—</td>
<td>✓п</td>
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<td>Demiris et al</td>
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<td>O[^e]</td>
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<td>—</td>
<td>Remote or assistive care technologies</td>
<td>Smart home device</td>
<td>✓</td>
<td>—</td>
<td>✓п</td>
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<td>58.30</td>
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<td>Monitoring system</td>
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<td>—</td>
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[^a]: MM — Mixed Methods[^b]: ✓п — Social interaction[^c]: E — Experimental[^d]: Q — Qualitative[^e]: O — Observational[^f]: G — Geographical
<table>
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<th>Authors</th>
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<td>Trans-Theoretical Model of Behavioral Change</td>
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<td>26</td>
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<td>✓</td>
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<td>18</td>
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<td>67</td>
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<td>Remote or assistive care technologies</td>
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<td>69.5</td>
<td>40</td>
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<td>mHealth¹</td>
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<td>TAM</td>
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<tr>
<td>Dugas et al [54]</td>
<td>United States</td>
<td>E</td>
<td>Primary care</td>
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<td>✓</td>
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<td>—</td>
<td>Regulatory Mode Theory</td>
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<tr>
<td>Holgersson and Söderström [55]</td>
<td>Sweden</td>
<td>Q</td>
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<td>77.5</td>
<td>—</td>
<td>Everyday technologies</td>
<td>E-services</td>
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</tr>
<tr>
<td>Khosla et al [56]</td>
<td>Australia</td>
<td>MM</td>
<td>Home care</td>
<td>5</td>
<td>80</td>
<td>—</td>
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<tr>
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<td>United States</td>
<td>S</td>
<td>Community dwelling</td>
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<td>77.2</td>
<td>60</td>
<td>Everyday technologies</td>
<td>—</td>
<td>—</td>
<td>✓</td>
<td>✓</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>Country</td>
<td>Study design</td>
<td>Setting</td>
<td>Sample size, n</td>
<td>Sample mean age (years)</td>
<td>Proportion of female, %</td>
<td>Technology type</td>
<td>Technology subtype</td>
<td>Purpose</td>
<td>Health and safety</td>
<td>Social interaction</td>
<td>Independence</td>
<td>Model used</td>
</tr>
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<tr>
<td>Kim et al [58]</td>
<td>Republic of Korea</td>
<td>S</td>
<td>Primary care</td>
<td>21</td>
<td>72</td>
<td>81</td>
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<td>Mobile app</td>
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<td>✓</td>
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<tr>
<td>Woo et al [59]</td>
<td>United States</td>
<td>Q</td>
<td>Home care</td>
<td>20</td>
<td>72.6</td>
<td>55</td>
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<td>✓</td>
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<td>UTAUTk</td>
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<tr>
<td>Ali et al [60]</td>
<td>Australia</td>
<td>Q</td>
<td>Other/undefined</td>
<td>14,798</td>
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<td>52</td>
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<td></td>
</tr>
<tr>
<td>Bernstein et al [61]</td>
<td>United States</td>
<td>S</td>
<td>Community dwelling</td>
<td>60</td>
<td>73.4</td>
<td>27</td>
<td>Everyday technologies</td>
<td>Computer and apps</td>
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<td>✓</td>
<td>✓</td>
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</tr>
<tr>
<td>Bevilacqua et al [62]</td>
<td>Italy</td>
<td>MM</td>
<td>Other/undefined</td>
<td>35</td>
<td>74</td>
<td>63</td>
<td>Remote or assistive care technologies</td>
<td>Robot</td>
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<td>✓</td>
<td>✓</td>
<td>—</td>
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<tr>
<td>Cohen-Mansfield et al [63]</td>
<td>Israel</td>
<td>Q</td>
<td>Home care</td>
<td>105</td>
<td>74</td>
<td>85</td>
<td>Everyday technologies</td>
<td>A gamified web-based activity program</td>
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<td>—</td>
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<tr>
<td>Doyle et al [64]</td>
<td>Ireland and Belgium</td>
<td>S</td>
<td>Home care</td>
<td>120</td>
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<td>40</td>
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<td>A digital health platform (ProACT)</td>
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<tr>
<td>Ghorayeb et al [65]</td>
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<td>Q</td>
<td>Home care</td>
<td>13</td>
<td>77</td>
<td>54</td>
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<td>Smart home devices</td>
<td>✓</td>
<td>—</td>
<td>✓</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Harris et al [66]</td>
<td>United States</td>
<td>S</td>
<td>Community dwelling</td>
<td>70</td>
<td>71.1</td>
<td>73</td>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>Kalicki et al [67]</td>
<td>United States</td>
<td>S</td>
<td>Community dwelling</td>
<td>873</td>
<td>82.7</td>
<td>75</td>
<td>Remote or assistive care technologies</td>
<td>Telehealth</td>
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<td>✓</td>
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<tr>
<td>Klaver et al [68]</td>
<td>The Netherlands</td>
<td>S</td>
<td>Primary care</td>
<td>463</td>
<td>74</td>
<td>49</td>
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<td>mHealth</td>
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<td>—</td>
<td>✓</td>
<td>TAMUTAUT</td>
<td></td>
</tr>
<tr>
<td>Li et al [69]</td>
<td>United States</td>
<td>S</td>
<td>Primary care</td>
<td>2909</td>
<td>77.2</td>
<td>55</td>
<td>Everyday technologies</td>
<td>Information and communications technology</td>
<td>—</td>
<td>✓</td>
<td>✓</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Marklund et al [70]</td>
<td>Sweden</td>
<td>Q</td>
<td>Primary care</td>
<td>16</td>
<td>72</td>
<td>75</td>
<td>Remote or assistive care technologies</td>
<td>eHealth</td>
<td>✓</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Fogg Behavior Model</td>
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<tr>
<td>Nebeker and Zlatar [71]</td>
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<td>R</td>
<td>Other/undefined</td>
<td>41</td>
<td>71.6</td>
<td>76</td>
<td>Remote or assistive care technologies</td>
<td>mHealth</td>
<td>✓</td>
<td>—</td>
<td>✓</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Pang et al [72]</td>
<td>Canada</td>
<td>MM</td>
<td>Community dwelling</td>
<td>42/27</td>
<td>69</td>
<td>43</td>
<td>Everyday technologies</td>
<td>Learning video prototype</td>
<td>—</td>
<td>—</td>
<td>✓</td>
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<td></td>
</tr>
<tr>
<td>Authors</td>
<td>Country</td>
<td>Study design</td>
<td>Setting</td>
<td>Sample size, n</td>
<td>Sample mean age (years)</td>
<td>Proportion of female, %</td>
<td>Technology type</td>
<td>Technology subtype</td>
<td>Purpose</td>
<td>Social interaction</td>
<td>Independence</td>
<td>Model used</td>
<td></td>
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<tr>
<td>Yachin and Nimrod [73]</td>
<td>Canada, Colombia, Israel, Italy, Peru, Romania, and Spain</td>
<td>S</td>
<td>Other/un-defined</td>
<td>184</td>
<td>71</td>
<td>100</td>
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<td>Information and communications technology</td>
<td>—</td>
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<td>✓</td>
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<td></td>
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<tr>
<td>Blavette et al [74]</td>
<td>France</td>
<td>S</td>
<td>Primary care</td>
<td>45</td>
<td>82</td>
<td>65</td>
<td>Remote or assistive care technologies</td>
<td>Robot</td>
<td>✓</td>
<td>✓</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Choi et al [75]</td>
<td>United States</td>
<td>MM</td>
<td>Community dwelling</td>
<td>3257</td>
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<td>56</td>
<td>Remote or assistive care technologies</td>
<td>Telehealth</td>
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<td>✓</td>
<td>—</td>
<td>Healthcare Utilization Model</td>
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<tr>
<td>Coley et al [76]</td>
<td>France</td>
<td>R</td>
<td>Community dwelling</td>
<td>2724</td>
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<td>48</td>
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<tr>
<td>Domingos et al [77]</td>
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<td>S</td>
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<td>110</td>
<td>69</td>
<td>66</td>
<td>Everyday technologies</td>
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<td>—</td>
<td>✓</td>
<td>TAM3m</td>
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</tr>
<tr>
<td>Gomez et al [78]</td>
<td>United Kingdom</td>
<td>O</td>
<td>Community dwelling</td>
<td>44</td>
<td>72</td>
<td>—</td>
<td>Remote or assistive care technologies</td>
<td>Hearing aid</td>
<td>✓</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Krutter et al [79]</td>
<td>Germany</td>
<td>MM</td>
<td>Home care</td>
<td>20</td>
<td>65</td>
<td>—</td>
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<td>Virtual avatar</td>
<td>✓</td>
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<tr>
<td>Özsungur [80]</td>
<td>Turkey</td>
<td>S</td>
<td>Home care</td>
<td>687</td>
<td>73</td>
<td>40</td>
<td>Everyday technologies</td>
<td>Online services and apps</td>
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<td>✓</td>
<td>✓</td>
<td>UTAUT 2</td>
<td></td>
</tr>
<tr>
<td>Qin [81]</td>
<td>United States</td>
<td>S</td>
<td>Community dwelling</td>
<td>1769</td>
<td>—</td>
<td>55</td>
<td>Remote or assistive care technologies</td>
<td>Telehealth</td>
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<td>✓</td>
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<td>—</td>
<td></td>
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<tr>
<td>Smrke et al [82]</td>
<td>Slovenia</td>
<td>S</td>
<td>Home care</td>
<td>185</td>
<td>81</td>
<td>66</td>
<td>Remote or assistive care technologies</td>
<td>Robot</td>
<td>—</td>
<td>✓</td>
<td>✓</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Vailati Riboni et al [83]</td>
<td>Italy</td>
<td>Q</td>
<td>Community dwelling</td>
<td>68</td>
<td>72</td>
<td>71</td>
<td>Everyday technologies</td>
<td>App</td>
<td>✓</td>
<td>—</td>
<td>✓</td>
<td>—</td>
<td></td>
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</tbody>
</table>
Different types of technology were examined, ranging from mobile technologies and television-based to assistive technologies, with the most common technology type being technology devices. Based on the scope of functionalities, 2 main categories of technology were summarized [85]: (1) everyday technologies (including hardware devices, such as computers, smartwatches, tablets, computers, and services such as gaming, apps, and other technologies used to support daily living); and (2) remote or assistive care technologies, which were those that use information communication technology devices and networks to deliver health and social care technology. Remote or assistive care technologies were most commonly reported (32/59, 54%).

The purpose of technology was also defined. Technology that supports older adults’ independence through activities of daily living or instrumental activities of daily living was the most common (40/59, 68%), followed by technology that aims to enhance safety (eg, such as monitoring or assistive technology; 36/59, 61%).

In a 2008 study [31], a model was used for the first time as a theoretical basis. Subsequently, studies from 2015 onward have used models for their studies. The studies did not show a trend in terms of setting, study design, technology type, and model use. Most study designs used were quantitative (27/59, 46%), followed by qualitative (21/59, 36%) and mixed methods (11/59, 19%).

Use of Theoretical Models

Only one-third (19/59) of the articles used 1 of the available theoretical models to explain older adults’ intention to use digital technology. The remaining articles provided descriptive evidence to support, formulate, or extend a theoretical model. Table 2 provides an overview of the theories used, the research fields they derive from, and the articles that applied them to their research. A classification of the 12 models based on academic discipline of their origin and the constructs applied by the corresponding research article is provided in Table 3. Table 4 presents a summary of the used constructs grouped into categories in articles that used and did not use a theoretical basis.
### Table 2. Use of theoretical models.

<table>
<thead>
<tr>
<th>Model used</th>
<th>Research field</th>
<th>Total</th>
<th>Article(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandura’s Self-Efficacy Theory</td>
<td>Psychology</td>
<td>1</td>
<td>[33]</td>
</tr>
<tr>
<td>Health Belief Model</td>
<td>Health</td>
<td>1</td>
<td>[31]</td>
</tr>
<tr>
<td>Hoymann’s Wellness Model</td>
<td>Health</td>
<td>1</td>
<td>[39]</td>
</tr>
<tr>
<td>Healthcare Utilization Model</td>
<td>Health</td>
<td>1</td>
<td>[75]</td>
</tr>
<tr>
<td>Regulatory Mode Theory</td>
<td>Sociopsychology</td>
<td>1</td>
<td>[54]</td>
</tr>
<tr>
<td>Self-Determination Theory</td>
<td>Sociopsychology</td>
<td>1</td>
<td>[47]</td>
</tr>
<tr>
<td>Trans-Theoretical Model of Behavioral Change</td>
<td>Sociopsychology</td>
<td>1</td>
<td>[44]</td>
</tr>
<tr>
<td>Fogg Behavior Model</td>
<td>Sociopsychology</td>
<td>1</td>
<td>[70]</td>
</tr>
<tr>
<td>Technology Acceptance Model</td>
<td>Information systems</td>
<td>6</td>
<td>[48,50,53,56,68,84]</td>
</tr>
<tr>
<td>Technology Acceptance Model 2</td>
<td>Information systems</td>
<td>1</td>
<td>[49]</td>
</tr>
<tr>
<td>Technology Acceptance Model 3</td>
<td>Information systems</td>
<td>1</td>
<td>[77]</td>
</tr>
<tr>
<td>Unified Theory of Acceptance and Use of Technology</td>
<td>Information systems</td>
<td>3</td>
<td>[59,68,79]</td>
</tr>
<tr>
<td>Unified Theory of Acceptance and Use of Technology 2</td>
<td>Information systems</td>
<td>1</td>
<td>[80]</td>
</tr>
<tr>
<td>Articles using models</td>
<td>N/Aa</td>
<td>19</td>
<td>N/A</td>
</tr>
<tr>
<td>No model used</td>
<td>N/A</td>
<td>40</td>
<td>N/A</td>
</tr>
<tr>
<td>Total articles</td>
<td>N/A</td>
<td>59</td>
<td>N/A</td>
</tr>
</tbody>
</table>

aN/A: not applicable.

### Table 3. Classification of the used models.

<table>
<thead>
<tr>
<th>Research field</th>
<th>Model</th>
<th>Constructs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information systems</td>
<td>• Technology Acceptance Model&lt;br&gt;• Technology Acceptance Model 2&lt;br&gt;• Technology Acceptance Model 3&lt;br&gt;• Unified Theory of Acceptance and Use of Technology&lt;br&gt;• Unified Theory of Acceptance and Use of Technology 2</td>
<td>Computer anxiety; Computer playfulness; Computer self-efficacy; Confirmed usefulness; Ease of learning and use; Experimentation and exploration; Facilitating conditions; Habit; Hedonic motivation; Image; Job relevance; Objective usability; output quality; Perceived ease of use; Perceived enjoyment; Perceived usefulness; Perception of external control; Price value; Result demonstrability; Social influence; Subjective norm; User context</td>
</tr>
<tr>
<td>Health</td>
<td>• Hoymann’s Wellness Model&lt;br&gt;• Health Belief Model&lt;br&gt;• Healthcare Utilization Model</td>
<td>Enabling factors (family support, access to health insurance); Mental and cognitive health; Perceived barriers; Perceived benefits; Perceived or actual needs; Perceived severity; Perceived susceptibility; Physical well-being; Predisposing factors (demographics); Social well-being; Spiritual well-being</td>
</tr>
<tr>
<td>Sociopsychology</td>
<td>• Fogg Behavior Model&lt;br&gt;• Trans-Theoretical Model of Behavioral Change&lt;br&gt;• Self-Determination Theory&lt;br&gt;• Regulatory Mode Theory</td>
<td>Ability; Autonomy; Competence; Consciousness raising; Counter-conditions; Dramatic relief; Environmental reevaluation; Helping relationships; Locomotion and assessment; Motivation; Promoting value; Prompts; Reinforcement management; Relatedness; Self-liberation; Self-reevaluation; Social liberation; Stimulus control</td>
</tr>
<tr>
<td>Psychology</td>
<td>• Bandura’s Self-Efficacy Theory</td>
<td>Emotional and physiological states; Performance outcomes (mastery experiences); Social persuasion; Social role models (vicarious experiences)</td>
</tr>
</tbody>
</table>
The information systems field developed the TAM (n=6), TAM2 (n=1), TAM3 (n=1), UTAUT (n=3), and UTAUT 2 (n=1). These models focused on core constructs of perceived usefulness and perceived ease of use, attitude toward using, and intention to use the system (eg, TAM). The UTAUT also included the construct social influence and facilitating conditions. Both the TAM and the UTAUT were further developed, including TAM2 (n=1) and TAM3 (n=1), which highlighted trust and perceived risk on system use, and UTAUT 2 (n=1), which incorporated 3 other constructs including hedonistic motivation (eg, the pleasure of using a technology), price-performance ratio, and habits.

Three models had their origin in health-related research. Both the Health Belief Model [86,87] and Hoyman’s Wellness Model [88] explored the multidimensional unit of health and wellness by emphasizing human health needs holistically within their environment by addressing 4 dimensions. Finally, Anderson’s Healthcare Utilization Model [89] aimed to understand how and why people use health care services, assess inequalities in accessing health services, and aid in the creation of policies that will allow for equitable access to care. To predict or explain one’s use of health care services, the model particularly focused on an individual’s predisposition to use acute health care services, enabling factors that facilitate use and one’s perceived or influenced need for care.

From the socio-psychological domain, the Trans-Theoretical Model of Behavioral Change [90] described an integrative theory of therapy that assesses an individual’s readiness to act on a new healthier behavior, providing strategies or processes of change to guide the individual. The model is composed of constructs such as stages of change, processes of change, levels of change, self-efficacy, and decisional balance. The Regulatory Mode Theory [91] described how people approach situations or influenced need for care.

Table 4. Summary of constructs grouped into categories.

<table>
<thead>
<tr>
<th>Demographics and Health Status</th>
<th>Emotional Awareness and Needs</th>
<th>Knowledge, Competence, and Perception</th>
<th>Motivation</th>
<th>Social Influencers</th>
<th>Functionals features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Anxiety</td>
<td>(Adequate) computer training</td>
<td>Benefits</td>
<td>Social influence</td>
<td>Cost</td>
</tr>
<tr>
<td>BMI</td>
<td>Application design</td>
<td>Education</td>
<td>Habit</td>
<td>Subjective norm</td>
<td>External influence</td>
</tr>
<tr>
<td>Chronic disease</td>
<td>Self-determination</td>
<td>(Previous) experience</td>
<td>Perceived threat</td>
<td>Interpersonal relationships</td>
<td>Facilitating conditions</td>
</tr>
<tr>
<td>Cognitive impairment</td>
<td>Self-efficacy</td>
<td>Self-esteem</td>
<td>Attitude</td>
<td>Peer relationships</td>
<td>Usability</td>
</tr>
<tr>
<td>Cognitive performance</td>
<td>Confidence</td>
<td>Confidence</td>
<td>Awareness</td>
<td>Learn with help</td>
<td>User friendliness</td>
</tr>
<tr>
<td>Depression</td>
<td>Emotional needs</td>
<td>Emotionality</td>
<td>Curiosity</td>
<td>Social capital</td>
<td>Ease of use</td>
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<td>Employer</td>
<td>Fear</td>
<td>Equipment needs</td>
<td>Equipment needs</td>
<td>Social isolation</td>
<td>Presence of useful features</td>
</tr>
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<td>Functional disability</td>
<td>Feelings</td>
<td>Perception of need</td>
<td>Perception of need</td>
<td>Social participation</td>
<td>Accessibility</td>
</tr>
<tr>
<td>Gender</td>
<td>Mood</td>
<td>Expectancy</td>
<td>Regularity</td>
<td>Social perceptions</td>
<td>Assurances of technology</td>
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<tr>
<td>Hearing ability</td>
<td>Need for emotional support</td>
<td>Perceived risk expectancy</td>
<td>Rewards</td>
<td>Personal influence</td>
<td>Compatibility</td>
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<td>Linguistic problems</td>
<td>Pain</td>
<td>Perceived usefulness</td>
<td>Lack of need for technology</td>
<td>Social participation</td>
<td>Feasibility</td>
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<td>Marital status</td>
<td>Fatigue</td>
<td>Beliefs</td>
<td>Willingness to learn</td>
<td>Social perception</td>
<td>Impressions of technology</td>
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<tr>
<td>Origin</td>
<td>Fatigue</td>
<td>Digital literacy</td>
<td>Reduced in-person healthcare</td>
<td>Personal influence</td>
<td>Inconvenience to use</td>
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<td>Sensory perception</td>
<td>Fatigue</td>
<td>Empowerment</td>
<td>Engagement</td>
<td>Support</td>
<td>Information quality</td>
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<tr>
<td>Income</td>
<td>Fatigue</td>
<td>Health literacy</td>
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<td>Social relations</td>
<td>Portal use</td>
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<td>Existing disease</td>
<td>Fatigue</td>
<td>Medication adherence</td>
<td></td>
<td>Physicians’ recommendation</td>
<td>Self-perceived effectiveness of use</td>
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<td>Medical history</td>
<td>Fatigue</td>
<td>Memory</td>
<td></td>
<td></td>
<td>Service ability</td>
</tr>
<tr>
<td>Loneliness</td>
<td>Fatigue</td>
<td>Misuse/overuse</td>
<td></td>
<td></td>
<td>Service quality</td>
</tr>
<tr>
<td>Physical activity</td>
<td>Fatigue</td>
<td>Patients’ choices</td>
<td></td>
<td></td>
<td>System quality</td>
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<tr>
<td>Presence of dementia</td>
<td>Fatigue</td>
<td>Perceived access barriers</td>
<td></td>
<td></td>
<td>Utility of technology for health</td>
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<td>Professional education</td>
<td>Fatigue</td>
<td>Personal innovativeness</td>
<td></td>
<td></td>
<td>Active versus passive communication</td>
</tr>
<tr>
<td>Quality of life</td>
<td>Fatigue</td>
<td>Previous experience</td>
<td></td>
<td></td>
<td>Ambiguous affordances</td>
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<tr>
<td>Religion</td>
<td>Fatigue</td>
<td>Privacy concerns</td>
<td></td>
<td></td>
<td>Poorly designed interface</td>
</tr>
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<td>Cultural issues</td>
<td>Fatigue</td>
<td>Satisfaction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical weakness</td>
<td>Fatigue</td>
<td>Self-management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trust in provider</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trust in system</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Learning a new technology</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Level of assessment/capability</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aConstructs not used in the models are given in italics.

The information systems field developed the TAM (n=6), TAM2 (n=1), TAM3 (n=1), UTAUT (n=3), and UTAUT 2 (n=1). These models focused on core constructs of perceived usefulness and perceived ease of use, attitude toward using, and intention to use the system (eg, TAM). The UTAUT also included the construct social influence and facilitating conditions. Both the TAM and the UTAUT were further developed, including TAM2 (n=1) and TAM3 (n=1), which highlighted trust and perceived risk on system use, and UTAUT 2 (n=1), which incorporated 3 other constructs including hedonistic motivation (eg, the pleasure of using a technology), price-performance ratio, and habits.

Three models had their origin in health-related research. Both the Health Belief Model [86,87] and Hoyman’s Wellness Model [88] explored the multidimensional unit of health and wellness by emphasizing human health needs holistically within their environment by addressing 4 dimensions. Finally, Anderson’s Healthcare Utilization Model [89] aimed to understand how and why people use health care services, assess inequalities in accessing health services, and aid in the creation of policies that will allow for equitable access to care. To predict or explain one’s use of health care services, the model particularly focused on an individual’s predisposition to use acute health care services, enabling factors that facilitate use and one’s perceived or influenced need for care.

From the socio-psychological domain, the Trans-Theoretical Model of Behavioral Change [90] described an integrative theory of therapy that assesses an individual’s readiness to act on a new healthier behavior, providing strategies or processes of change to guide the individual. The model is composed of constructs such as stages of change, processes of change, levels of change, self-efficacy, and decisional balance. The Regulatory Mode Theory [91] described how people approach situations or influenced need for care.

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explains behavioral motivation as dependent on whether basic psychological needs for competence, social inclusion, and autonomy can be satisfied.

From the research field psychology, the Self-Efficacy Theory [94] explained how well a person that can cope with the particular situation is dependent on the skills they have and the circumstances they face.

### Technology Types and Purpose

Articles showed that older adults had varying acceptance levels to different forms of technology. Two different types of digital technologies were found that focused on (1) everyday technologies or (2) remote or assistive care technologies (Table 5). We further assigned these types by purpose using categories identified by Peek et al [11] that explored how the technology type supported the users’ health and safety, social interaction, or independence.

<table>
<thead>
<tr>
<th>Technology Purpose</th>
<th>Technology Type</th>
<th>Article(s)</th>
<th>Model used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independence</td>
<td>Remote or assistive care technologies</td>
<td>—</td>
<td>Fogg Behavior Model [70]</td>
</tr>
<tr>
<td>Social interaction</td>
<td></td>
<td>—</td>
<td>Health Belief Model [31]</td>
</tr>
<tr>
<td>Health and safety</td>
<td></td>
<td>—</td>
<td>Hoyman’s Wellness Model [39]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>Healthcare Utilization Model [75]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>Regulatory Mode Theory [54]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>Self-Determination Theory [47]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>Bandura’s Self-Efficacy Theory [33]</td>
</tr>
<tr>
<td></td>
<td>Everyday technologies</td>
<td>1-5</td>
<td>Technology Acceptance Model [48,53,56,68,84]</td>
</tr>
<tr>
<td></td>
<td>Remote or assistive care technologies</td>
<td>1</td>
<td>Technology Acceptance Model 2 [49]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Technology Acceptance Model 3 [77]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Trans-Theoretical Model of Behavioral Change [44]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Unified Theory of Acceptance and Use of Technology [59,68,79]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Unified Theory of Acceptance and Use of Technology 2 [80]</td>
</tr>
</tbody>
</table>

*Data not available.*

Models were more commonly applied to remote or assistive care technologies (15/19, 79%), with the TAM and UTAUT models identified in more than 1 article [68]. Other models were used less frequently. Similarly, only the TAM, UTAUT, and UTAUT 2 models were found in articles exploring all 3 technology purposes (eg. [59,68,79,80]).

### Technology Types by Setting

The setting in which the research participants reside is expected to have a major influence on their intention to use digital technology. Thus, we analyzed which technology types were studied in what setting. Table 6 provides the corresponding overview.

The setting most studied was community dwelling (24/59, 41%), followed by primary care (13/59, 22%) and home care (12/59, 20%). Community dwelling refers to older people who live independently within the community. Primary care refers to health services that include a range of preventive, wellness, and treatment measures for common diseases. Primary care providers include doctors, nurses, nurse practitioners, and health care professionals. Home care refers to the nursing and domestic care of people in need of care outside of partial or full inpatient facilities in their home environment. Overall, technology types were relatively distributed between settings, although home care and primary settings tended to have more remote or assistive care technology types, while everyday technologies were more likely to be found in community dwelling and community centers.
Table 6. Technology types studied in different settings by articles.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Technology type</th>
<th>Everyday technology (n=27), n (%)</th>
<th>Remote or assistive care technology (n=32), n (%)</th>
<th>Total (N=59)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community center</td>
<td>Remote or assistive care technology (n=32), n (%)</td>
<td>2 (67)</td>
<td>1 (33)</td>
<td>3</td>
</tr>
<tr>
<td>Community dwelling</td>
<td>Remote or assistive care technology (n=32), n (%)</td>
<td>13 (57)</td>
<td>10 (43)</td>
<td>23</td>
</tr>
<tr>
<td>Home care</td>
<td>Remote or assistive care technology (n=32), n (%)</td>
<td>4 (33)</td>
<td>8 (67)</td>
<td>12</td>
</tr>
<tr>
<td>Long-term care</td>
<td>Remote or assistive care technology (n=32), n (%)</td>
<td>1 (50)</td>
<td>1 (50)</td>
<td>2</td>
</tr>
<tr>
<td>Primary care</td>
<td>Remote or assistive care technology (n=32), n (%)</td>
<td>5 (38)</td>
<td>8 (62)</td>
<td>13</td>
</tr>
<tr>
<td>Other/undefined</td>
<td>Remote or assistive care technology (n=32), n (%)</td>
<td>2 (33)</td>
<td>4 (67)</td>
<td>6</td>
</tr>
</tbody>
</table>

Factors Contributing to Older Adults’ Intention to Use Digital Technology

Overview of Categories

Table 7 provides a list of the constructs used to explain and predict older adults’ intention to adopt technology. To provide a meaningful analysis of the numerous constructs we grouped them into 6 categories: Demographics and Health Status, Emotional Awareness and Needs, Knowledge and Perception, Motivation, Social Influencers, and Technology Functional Features (for further information on these constructs, see Table 4 and Multimedia Appendix 1). Table 7 shows the number of articles that applied a specific category to a certain technology type.

Table 7. Articles reporting an intention to use technology by category and technology type.

<table>
<thead>
<tr>
<th>Category</th>
<th>Articles that applied this category (N=59), n (%)</th>
<th>Technology type</th>
<th>Everyday technologies, n (%)</th>
<th>Remote or assistive care technologies, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics and Health Status</td>
<td>37 (63)</td>
<td>15 (41)</td>
<td>22 (59)</td>
<td></td>
</tr>
<tr>
<td>Emotional Awareness and Needs</td>
<td>21 (36)</td>
<td>11 (52)</td>
<td>10 (48)</td>
<td></td>
</tr>
<tr>
<td>Knowledge, Competence, and Perception</td>
<td>40 (68)</td>
<td>15 (38)</td>
<td>25 (62)</td>
<td></td>
</tr>
<tr>
<td>Motivation</td>
<td>24 (41)</td>
<td>12 (50)</td>
<td>12 (50)</td>
<td></td>
</tr>
<tr>
<td>Social Influencers</td>
<td>22 (37)</td>
<td>11 (50)</td>
<td>11 (50)</td>
<td></td>
</tr>
<tr>
<td>Functional Features</td>
<td>36 (61)</td>
<td>16 (44)</td>
<td>20 (56)</td>
<td></td>
</tr>
</tbody>
</table>

The most commonly identified category was Knowledge, Competence, and Perception (40/59, 68%), which explored how education, privacy concerns, trust in the provider, and health literacy influenced behavioral intention. This was followed by Demographics and Health Status (37/59, 63%), which explored the concepts of age, gender, origin, as well as health status and medical history. Functional Features was also frequently described (36/59, 61%) and considered how technical capabilities and concepts such as better information quality, interoperability, and service and system quality affected behavioral intention.

Overall, technology types were relatively distributed between the categories. Remote or assistive care technologies were observed more frequently in the categories of Knowledge, Competence, and Perception (25/40, 63%) and Demographics and Health Status (22/37, 59%). More detailed descriptions of the categories and their direction of influence are described in the following sections.

Demographics and Health Status

Health limitations such as physical inability, presence of dementia, functional disabilities, and other diseases had a negative impact on the intention to use digital technology. By contrast, marital status, healthy BMI, and higher income were linked with higher behavioral intention. These individual factors as well as age were also considered moderators in other studies.

Emotional Awareness and Needs

This category explored the concepts of anxiety, fear, self-determination, self-efficacy, and pain, and was reported across the majority of technology types. Older adults’ self-determination, stigma-consciousness, and self-efficacy were linked to increased behavioral intention. By contrast, resistance to change, fear, and anxiety were found to negatively impact on the intention to use digital technology.

Knowledge, Competence, and Perception

Older adults that had high perceived risk during technology use, privacy concerns, or lack of trust in the provider and the system, poor prior experience, low knowledge, and low health literacy had lower behavioral intentions. By contrast, if older adults could make their own choices, had prior computer training, had positive expectancy, and had prior strong satisfaction, they would be more likely to use the technology.

Motivation

This category reflected users’ motives and intention. Concepts included perceived need for the technology, available rewards, attitudes, goals, and habits. Individuals were more likely to use
technology when they set health goals and perceived a need to use a technology to support their goal.

**Social Influencers**

This category considered social determinants of general social pressure on a person to engage in a particular behavior and included factors such as isolation, participation, social capital, and network support. The presence of positive social support supported behavioral intention in 11 articles in each technology type.

**Functional Features**

This category described the technical characteristics of a technology that fulfill a specific function. This included factors such as accessibility, usability, cost, system and service quality, and design. Users who could operate a technology better found the design more appealing, and were technically more capable and more likely to adopt the technology.

**Conceptual Framework**

Based on the information derived from our review, there were 6 clusters of influencing factors from sociopsychological, psychological, and health information fields, which describe older adults’ intention to use digital technology. We have combined these to present a unified perspective, which provides a more comprehensive and collective view of the factors influencing older adults’ behavioral intention across multiple disciplines (Figure 2). This framework emphasizes the interconnected role of the 6 constructs that influence older adults’ intention to use technology across multiple technology types.

**Quality Appraisal**

Overall, the quality of the studies was strong for qualitative and quantitative research designs, and moderate for mixed method designs (Multimedia Appendix 1). Most qualitative studies (17/21) had a clear research question, with 95% (20/21) of articles describing results appropriately. The qualitative articles that were screened using the Critical Appraisal Skills Program method largely met the requirements. One criterion for consideration of ethical issues was met by one-third of the articles examined [35,37,50].

The quantitative articles, which were examined with the MMAT and the Cochrane Risk of Bias screening criteria, were able to fulfil the criteria across the board. Most quantitative articles had a low bias. The MMAT criteria were largely met.

For mixed method articles, the quality of 1 [46] out of 11 articles could not be fully assessed because we considered the research question of this article to be unclear. The remaining mixed method articles satisfied the majority of the criteria (10/11, 91%). One article [79] did not show exact outcomes; thus, the criteria could not be fulfilled unambiguously.

**Discussion**

**Principal Findings**

In our mapping review, we found that older ‘adults’ intention to use technology was driven by 6 different categories: Demographics and Health Status; Emotional Awareness and Needs; Knowledge, Competence, and Perception; Motivation; Social Influencers; and Actual Technology Features. These categories could be mapped to 2 different main technology types (everyday technologies and remote or assistive care technologies) and 3 purposes (health and safety, social interaction, and independence).

Our mapping review provides an overview of the application of existing theoretical models of technology acceptance while...
identifying additional key factors contributing to the intention to use digital technology among older adults. Most articles did not describe an existing technology adoption model. In the last 4 decades we found insufficient attention on research of technology adoption models specifically in the health sector, and more recent empirical research presenting major gaps in the actual application of theoretical models. Most articles lacked an explicit theoretical approach, which makes it difficult to interpret and compare the results of studies in this area.

New models incorporating constructs such as belief, resilience, and health status to facilitate the intention to use digital technology for older adults were found, alongside previous reports of individual influencing factors (eg, age, gender). Synonymous with previous reviews on the topic of technology acceptance and intention to use, our review suggests that despite 2 models being popularly used (TAM and UTAUT), older adults’ acceptance of technology was influenced by factors beyond the key constructs of these models.

Existing reviews have investigated older adults’ acceptance and intention to use technology across multiple phases of technology implementation [95-98]. Similar to the extrapolations of our mapping review, other reviews have found diversity in the variables influencing intention to use digital technology among older adults, with individual variables also being considered. This includes age (eg, older age); health status factors such as mobility issues (eg, fractured wrists and fingers) and vision discomfort; technology features; and support factors such as ongoing costs and accessibility of instructions and guidance [97]. A recent meta-analysis also highlighted that social influences (ie, conversations with family, friends, and professional caregivers) had a strong impact on the intention to use digital technology, especially when it is new and in the beginning of the adoption stages [96]. Factors including personality, beliefs, and resilience were found in our review, suggesting a dynamic influence of psychosocial traits on technology. These preferences and concerns adjust over the course of time and technology implementation [98,99].

There have been multiple studies exploring how existing technology models contribute to older adults’ intention to adopt technology. However, research on technology adoption and older people should go beyond describing facilitators and barriers [100]. Instead, a better understanding of the environment of older people and their interaction with this environment should be developed [100]. We believe that uncovering the role of communication and interaction between older people and their environment should be a key health research concern, as a means of contributing to improved care for older people in the community.

Taken together, the findings from this mapping review have important repercussions on the validity and applicability of popular theoretical models of technology adoption and intention to use digital technology. Our findings correspond with those of previous research expressing concern about the impact of unexplored factors along with their potential interaction with key components of commonly used technology adoption models and their subsequent reduced predictive ability [95]. We have used the findings of previous research along with the additional constructs found in our mapping review to suggest contributions to the discourse around technology adoption and intention to use digital technology specifically in relation to older adults.

Implications for Research

Traditional models of technology adoption have been largely developed from information systems and health behavior models (eg, Table 3, Figure 2). However, factors from different disciplines have not been successfully combined so far. It has been shown that health-related and social-psychological factors also represent a major element in the adoption of technology, especially for older people. Our mapping review highlights that traditional information system models such as the TAM and UTAUT require the implementation of health and psychology constructs. Here, we identified a significant gap in the research. Furthermore, it is essential to note that existing models do not particularly focus on the age of technology users. The importance and awareness of the role of age in information systems were already highlighted by Tams et al [101]. They pointed out that future research needs to focus more extensively on cognitive age rather than on physical age, as older people show difficulties especially in dealing with complex and contemporary technologies. Perceived physical old age as opposed to cognitive old age, as well as perceived health status, constitutes further factors of investigation.

The advantage of this approach is that it emphasizes the relevant beliefs and antecedents for general intention to use digital technology and, consequently, provides more directive insights for the design of intention to use digital technology. Based on results, we underline the nature of personality (eg, attitude, self-efficacy expectation, resistance to change, resilience), emotions and social influences as well as the cognitive age, which are linked to health-promoting or health-damaging behavior and can have an activating effect on the intention to use digital technology [102,103]. Alternative factors including demographic and health data should be incorporated to ensure models can be applied appropriately (ie, at multiple stages of implementation), are flexible (ie, to account for different types of technology and changing older adult preferences), as well as being both individual- and context-dependent to assist with sustained intention to use digital technology (eg, inclusive of health status and disabilities). However, application of our framework should be considered in the context of the research objective and adapted accordingly. For example, while these constructs provide a basis for understanding early users’ intention to use digital technology by specifically focusing on the attitudinal, social, and normative belief structure, functional features of the technology type need to be considered for the design, implementation, and intention to use digital technologies (eg, ease of interoperability, size of screen), as well as the research question.

Limitations and Further Research

Our review had a comprehensive search strategy covering social sciences, health care, and technology fields. However, it found a relatively small number of studies covering broad technology types and included limited theory-based studies as well as studies in conference proceedings. However, as ours is a mapping review, we focused mainly on identifying
evidence-based gaps and trends across technology adoption in older adults more generally and the work was intended to be broad in scope. This may result in studies being overlooked (eg, from other databases and conference proceedings that are not peer-reviewed). Future studies should expand the scope to identify other factors and outcome variables, with more specific terms to capture wider forms of technology (eg, “digital assistants” or “bots”), as well as more inclusive eligibility criteria.

An additional limitation is that we discuss the stated theoretical models as equivalents without elaborating on their respective quality criteria. Previous research has already examined these models in the context of their research and shown variances, but there are considerably more opportunities to examine different age groups especially and to constantly include newly developed technologies. Future research could focus further on individual models in connection with specific categories of new and innovative technologies. Here, the focus should be on the health sector in particular. Existing studies were dominated by references to the TAM and UTAUT. Studies that pay more attention to interaction dimensions, emotional dimensions, and other resilience factors were lacking. Future research should bring these paradigms closer. While data on factors influencing use in the preadoption phase are extensive, findings on the postadoption phase were limited. To support the independence of community-dwelling older people over long periods, more research is needed to understand what influences the continued or sustained intention to use digital technologies after their introduction. Furthermore, additional quantitative research is required to understand which factors may have a greater impact than others and to examine the moderating or mediating relationships between factors.

Conclusion

Technology acceptance is influenced by numerous factors. Existing models of technology acceptance should be more intensively integrated and revised. However, there is limited research on technology acceptance among older adults. Further research targeting understanding of the complexity and timing of the acceptance process of different types of technology by older adults is warranted.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Additional details on data extraction and quality appraisal.

References


46. Chopik WJ. The Benefits of Social Technology Use Among Older Adults Are Mediated by Reduced Loneliness. Cyberpsychol Behav Soc Netw 2016 Sep;19(9):551-556 [FREE Full text] [doi: 10.1089/cyber.2016.0151] [Medline: 27541746]


76. Coley N, Andre L, Hoevenaar-Blom MP, Ngunu T, Beishuizen C, Barbera M. HATICE study group. PRODEMOS study group. Factors Predicting Engagement of Older Adults With a Coach-Supported eHealth Intervention Promoting Lifestyle Change and Associations Between Engagement and Changes in Cardiovascular and Dementia Risk: Secondary Analysis
of an 18-Month Multinational Randomized Controlled Trial. J Med Internet Res 2022 May 09;24(5):e32006 [FREE Full text] [doi: 10.2196/32006] [Medline: 35385395]


Abbreviations

mHealth: mobile health
MM: mixed method
MMAT: Mixed Methods Appraisal Tool
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
TAM: Technology Acceptance Model
TAM2: Technology Acceptance Model 2
TAM3: Technology Acceptance Model 3
UTAUT: Unified Theory of Acceptance and Use of Technology
UTAUT 2: Unified Theory of Acceptance and Use of Technology Model 2

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A Novel Digital Digit-Symbol Substitution Test Measuring Processing Speed in Adults At Risk for Alzheimer Disease: Validation Study

Anthony Campitelli¹, MS; Sally Paulson¹, PhD; Josh L Gills¹, MS; Megan D Jones¹, MS; Erica N Madero², MS; Jennifer Myers², PhD; Jordan M Glenn², PhD; Michelle Gray¹, PhD

¹Exercise Science Research Center, University of Arkansas, Fayetteville, AR, United States
²Neurotrack Technologies, Inc, Redwood City, CA, United States

Corresponding Author:
Michelle Gray, PhD
Exercise Science Research Center
University of Arkansas
308 HPER Building
115 Stadium Drive
Fayetteville, AR, 72701
United States
Phone: 1 479 575 6762
Fax: 1 479 575 2853
Email: rgray@uark.edu

Abstract

Background: Assessing cognitive constructs affected by Alzheimer disease, such as processing speed (PS), is important to screen for potential disease and allow for early detection. Digital PS assessments have been developed to provide widespread, efficient cognitive testing, but all have been validated only based on the correlation between test scores. Best statistical practices dictate that concurrent validity should be assessed for agreement or equivalence rather than using correlation alone.

Objective: This study aimed to assess the concurrent validity of a novel digital PS assessment against a gold-standard measure of PS.

Methods: Adults aged 45-75 years (n=191) participated in this study. Participants completed the novel digital digit-symbol substitution test (DDSST) and the Repeatable Battery for the Assessment of Neuropsychological Status coding test (RBANS-C). The correlation between the test scores was determined using a Pearson product-moment correlation, and a difference in mean test scores between tests was checked for using a 2-tailed dependent samples t test. Data were analyzed for agreement between the 2 tests using Bland-Altman limits of agreement and equivalency using a two one-sided t tests (TOST) approach.

Results: A significant moderate, positive correlation was found between DDSST and RBANS-C scores (r=.577; P<.001), and no difference in mean scores was detected between the tests (P=.93). Bias was nearly zero (0.04). Scores between the tests were found to display adequate agreement with 90% of score differences falling between –22.66 and 22.75 (90% limits of agreement=–22.91 to 22.99), and the scores were equivalent (P=.049).

Conclusions: Analyses indicate that the DDSST is a valid digital assessment of PS. The DDSST appears to be a suitable option for widespread, immediate, and efficient PS testing.

Trial Registration: ClinicalTrials.gov NCT04559789; https://clinicaltrials.gov/ct2/show/NCT04559789

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KEYWORDS

Alzheimer disease; dementia; processing speed; digit-symbol substitution; aging; cognitive
**Introduction**

Currently, Alzheimer disease (AD) affects more than 6 million Americans, and by the year 2050, this number is expected to rise to more than 13 million [1]. One in 3 seniors will die while experiencing AD or a related dementia, and the yearly deaths directly attributable to AD account for more than breast and prostate cancer combined [1]. AD and associated dementias also incur a substantial economic and social cost. It is estimated that in 2021, these cognitive diseases cost Americans US $355 billion; this figure is projected to rise to US $1.1 trillion by 2050. Socially, in 2020, more than 11 million unpaid caregivers worked 15.3 billion hours providing support for individuals with AD and related dementias—their time is valued at US $257 billion in lost wages [1]. Recognizing this dismal outlook, the research community has investigated many of the cognitive constructs associated with the disease in an effort to better understand the progression of the illness, detect signs earlier, and potentially develop methods to mitigate it [2].

One cognitive construct researchers have investigated in the context of AD is processing speed (PS). PS is defined as the rate at which an individual can analyze cognitive stimuli and complete cognitive tasks [3,4], and it has been shown to decrease significantly in individuals with mild cognitive impairment and further still in individuals with AD [3]. As such, PS is an important component in cognitive assessment protocols and AD-monitoring programs [5]. Although laboratory- and clinic-based assessments of PS have been developed [5], the limited availability of these tests concerns researchers as neurobiological decline can occur 15 years before any cognitive deficits are measurable, indicating that testing should take place frequently and ubiquitously to ensure that cognitive decline is detected as early as possible [2,6,7]. More recently, to address the need for widespread, rapid testing, researchers have focused on the development of digital cognitive tests that can be taken quickly on a mobile device and demonstrate high scalability, efficiency, and convenience [6,8]. Although several digital PS tests have been developed and presented as valid assessments [9-11], the validation procedures followed in these studies only examined the linear relationship between novel test scores and a gold-standard test, not the agreement between individuals scores as is required for proper validation [12]. The purpose of this study was to validate a novel PS task, a digital digit-symbol substitution test (DDSST), by examining its concurrent validity through comparison to a gold-standard test of PS. As tests of digit-symbol coding have been identified as gold-standard measures of PS [13], the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) coding test (RBANS-C) [14,15] was chosen as a comparison for its validity in the population analyzed in this study [15].

**Methods**

**Study Design**

This study implemented a cross-sectional design to evaluate concurrent validity between instruments. As a validation study, no random assignment was possible or required. Additionally, no form of blinding was used in this study design.

**Participants**

The goal sample size for this study was set at 200 participants to ensure adequate statistical power while allowing for potential attrition and incomplete data. Criteria for inclusion were adults aged between 45 and 75 years, BMI between 18.5 and 39.9 kg/m², and at least two of the following Alzheimer risk factors: high school education or less; BMI >25; and history of diabetes, hypertension, high cholesterol, or smoking. Participants were excluded if they had a diagnosed mental health condition, dementia, probable dementia, mild cognitive impairment, or other major health condition; a recent cardiovascular event; vision problems that would prevent viewing of a screen; learning disability; or more than one of the following Alzheimer protective factors: a high level of physical activity, a high level of fish consumption, or a high level of cognitive engagement. Participants were recruited in northwest Arkansas using local radio, emails, social media advertisements, news releases, and word of mouth.

**Procedure**

Participants reported to the laboratory and completed the RBANS assessment with an experienced test administrator. RBANS assessment procedures are described in detail elsewhere [14], but briefly, the RBANS-C assessment asks participants to match sequential symbols with corresponding numbers from a key on the same page, writing the correct number below each symbol. The RBANS-C raw score is calculated as the number of correct numbers filled in within 90 seconds. Assessments were scored by an experienced test administrator in accordance with the RBANS Testing Manual [14].

After a minimum of 30 minutes of unrelated physical testing, participants were instructed to begin using the self-guided cognitive testing platform (Neurotrack Digital Testing Platform; Neurotrack Technologies Inc) containing the DDSST test. The DDSST is based on the Digit Symbol Substitution Test [16]. The assessment provided both written and visual step-by-step, on-screen instructions; asked participants to determine if 2 symbols were equal or unequal based on a legend with 9 number-symbol pairs (Figure 1); and was objectively scored based on accuracy and speed using Neurotrack’s automated scoring algorithm. Specifically, raw scores were calculated as the number of correct responses given in 2 minutes. Data for this study were collected as part of an ongoing parent study (Digital Cognitive Multi-domain Alzheimer’s Risk Velocity [DC MARVel] Study) that is longitudinally examining changes in cognition and AD risk measures in at-risk adults randomized into either a health education or health-coaching intervention [17]. Further information regarding other subtests found in the Neurotrack Digital Testing Platform can be found in the published protocol for the DC MARVel Study [17].
**Data Analysis**

All statistical analyses were performed utilizing the `Analyse-It` extension for Microsoft Excel. The linear relationship between the RBANS-C and DDSST raw scores was calculated using a Pearson product-moment correlation. For tests of mean differences, agreement, and equivalency, the raw scores for both tests were scaled to a distribution with a mean of 100 and an SD of 15 to allow for the direct comparison of scores without impacting the distribution of scores or the appropriateness of the tests being used. In the case of scaling the RBANS-C score, the obtained score was converted to a z score based on the accepted population mean and SD for RBANS-C raw scores and then multiplied by 15, but as no accepted DDSST population mean and SD exists, those obtained from this study were used. Differences between group means were assessed using a 2-tailed dependent samples t test. Agreement was assessed with a Bland-Altman limits of agreement (LoA) plot with a 90% LoA. The LoA cutoff was set at the mean bias plus or minus the minimum reliable change (RC) score for the RBANS-C test obtained from previous literature (z=1.53) [12]. Researchers have stressed that RC is a more appropriate metric for assessing minimum change in the RBANS test than the minimum clinically important difference or standard error of measure [18]. A mountain plot was also generated to assess the y-axis distribution of the mean-difference plot.

Equivalency was tested using a two one-sided t tests (TOST) analysis, and the equivalency upper and lower bounds were determined [19] using the RBANS RC score obtained from previous literature described above. An a priori α level of .05 was used for all appropriate analyses.

**Ethics Approval**

This study was approved by the Institutional Review Board at the University of Arkansas (protocol #2009280813).

**Informed Consent**

Participants were informed of their rights as research participants and clearly notified that their participation was voluntary and they could withdraw at any time. All participants signed an approved consent form in accordance with the ethical standards of Helsinki.

**Results**

**Participants**

In total, 210 participants were initially enrolled in this study. After pretest attrition and adjusting the data set for incomplete testing data, a final sample of 191 adults (female: n=138; male: n=53) was analyzed. The average age of the sample was 62.2 (SD 8.27) years. Further descriptive statistics are presented in Table 1.
Table 1. Participant descriptive statistics (n=191).

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value, mean (SD)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>62.2 (8.27)</td>
<td>63.4-61.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.5 (9.13)</td>
<td>168.8-166.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>84.9 (18.23)</td>
<td>87.5-82.3</td>
</tr>
<tr>
<td>BMI (kg/m^2)</td>
<td>30.1 (5.22)</td>
<td>30.9-29.4</td>
</tr>
<tr>
<td>RBANS-C^a score^b</td>
<td>49.4 (8.09)</td>
<td>50.6-48.3</td>
</tr>
<tr>
<td>DDSST^c score^b</td>
<td>26.1 (6.57)</td>
<td>27.1-25.2</td>
</tr>
</tbody>
</table>

^aRBANS-C: Repeatable Battery for the Assessment of Neuropsychological Status coding test.
^bRBANS-C and DDSST scores are presented as raw scores here.
^cDDSST: digital digit-symbol substitution test.

Data Analysis
The moderately positive correlation obtained for the RBANS-C raw score and DDSST raw score was statistically significant ($r=.577; P<.001$). A 2-tailed dependent-samples t test showed no significant differences between the RBANS-C and DDSST scores within participants ($t_{190}=-0.09; P=.93$). Bland-Altman plots revealed the 90% LoA ($-22.66$ to $22.75$) was within the a priori cutoff ($-22.91$ to $22.99$), indicating that the scores for RBANS-C and DDSST were in acceptable agreement. Additionally, the mean bias score was near zero (0.04), indicating low systemic bias in scores, and there was no obvious linear pattern in the scatter plot distribution (Figure 2). The mountain plot distribution was roughly symmetrical, had a peak close to zero bias, and had no obvious tail skew (Figure 2). TOST analysis indicated that the scores for RBANS-C and DDSST were equivalent.

Discussion
Principal Findings
The purpose of this study was to assess the concurrent validity of a novel DDSST test as compared to the RBANS-C, a gold-standard measure of PS. Results showed no statistically significant differences in mean test scores within participants; a significant, moderately positive correlation in individual test scores; and acceptable agreement and equivalency between the 2 assessments. These results indicate that the DDSST is a valid assessment tool for evaluating PS in the sample of middle-age and older adults.

Impact
The potential impact of an assessment such as the DDSST is greater when the efficiency, scalability, and convenience of a digitally enabled test is considered. Digital tests allow the instant reporting of results to the test taker and potentially clinicians; the immediate and ad hoc distribution of tests to any number of test takers; and the convenience of having the ability to take tests anywhere, at any time.

Compared to previous studies validating digital assessments of PS, the relationship between the novel test and gold-standard test was lower here ($r=.577$ vs $r=.75-.8$) [10,11]. Validation, however, should not be based upon correlation between scores as this does not accurately demonstrate agreement between individual scoring pairs but rather an overall linear relationship.
that minimizes residuals [12]. Of the previous studies of digital instruments evaluating PS reviewed by the authors, none analyzed or reported the agreement between paired measures from novel and gold-standard tests in their assessment of concurrent validity [9-11]. As such, this study conducted a more comprehensive analysis of concurrent validity through the additional examination of agreement and appears to be the first study of a digital PS test to base its validation on those criteria.

Limitations

First, this study may have been limited by its protocol. It was carried out as part of a larger trial, and the order of testing was not randomized in the protocol to minimize learning effects or cognitive fatigue effects. Second, the sampling procedure specifically excluded individuals with cognitive impairments. By excluding segments that exist in the general population, generalizability is reduced. Third, intrarater and test-retest reliability could not be assessed for the novel DDSST instrument as repeat trials were not conducted as a part of this data set.

Data Availability

The data sets generated or analyzed during the current study are not publicly available due to the ongoing nature of the parent study, but aggregate data specific to the present study are available from the corresponding author on reasonable request.

Conflicts of Interest

ENM was an employee at Neurotrack Technologies while this work was completed and received salary and stock options. JM and JMG are employees at Neurotrack Technologies and receive salary and stock options as part of their employment.

References


**Abbreviations**

AD: Alzheimer disease

DC MARVel: Digital Cognitive Multi-domain Alzheimer’s Risk Velocity

DDSSST: digital digit-symbol substitution test

LoA: limits of agreement

PS: processing speed

RBANS: Repeatable Battery for the Assessment of Neuropsychological Status

RBANS-C: Repeatable Battery for the Assessment of Neuropsychological Status coding test

RC: reliable change

TOST: two one-sided t tests

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Individualistic Versus Collaborative Learning in an eHealth Literacy Intervention for Older Adults: Quasi-Experimental Study

Christian Elias Vazquez, PhD; Bo Xie, PhD; Kristina Shiroma, MLS; Neil Charness, PhD

1 School of Social Work, The University of Texas at Arlington, Arlington, TX, United States
2 School of Nursing, The University of Texas at Austin, Austin, TX, United States
3 School of Information, The University of Texas at Austin, Austin, TX, United States
4 Department of Psychology, Florida State University, Tallahassee, FL, United States

Corresponding Author:
Christian Elias Vazquez, PhD
School of Social Work
The University of Texas at Arlington
211 S Cooper St
Arlington, TX, 76019
United States
Phone: 1 8052596963
Email: christian.vazquez@uta.edu

Abstract

Background: Older adults tend to have insufficient health literacy, which includes eHealth literacy—the ability to access, assess, and use digital health information. Interventions using methods such as collaborative learning (CL) and individualistic learning (IL) may be effective in addressing older adults’ low eHealth literacy, but little is known about the short- and long-term effects of CL versus IL on older adults’ eHealth literacy.

Objective: The objective of this study was to use a 3 × 2 × 3 mixed factorial design to examine older adults’ learning with CL versus IL for eHealth literacy.

Methods: Older adults (N=466; mean age 70.5, SD 7.2; range 60-96 years) from diverse racial and ethnic groups were randomly assigned to either the CL or IL group (233/466, 50% in each). The intervention consisted of 4 weeks of training in 2-hour sessions held twice a week. Using ANOVA and multiple regression, we focused on the main effects of learning condition and interaction between learning condition and previous computer experience. Learning method (CL or IL) and previous computer experience (experienced, new, or mixed) were between-subject variables, and time of measurement (pretest measurement, posttest measurement, and 6-month follow-up) was the within-subject variable. Primary outcome variables were eHealth literacy efficacy, computer and web knowledge, basic computer and web operation skills, information-seeking skills, and website evaluation skills. Control variables were age, sex, education, health status, race and ethnicity, income, primary language, and previous health literacy.

Results: eHealth literacy efficacy, computer and web knowledge, basic computer and web operation skills, information-seeking skills, and website evaluation skills improved significantly (P<.001 in all cases) from before to after the intervention. From postintervention measurement to 6-month follow-up, there was a significant interaction between learning condition and previous computer experience based on 1 outcome measure, computer and web operation skills (F_{2,55}=3.69; P=.03). To maintain computer and web operation skills 6 months after the intervention, it was more effective for people with little to no previous computer experience to learn individually, whereas for people with more previous computer experience, it was more effective to learn collaboratively. From postintervention measurement to 6-month follow-up, statistically significant decreases were found in 3 of the 5 outcome measures: eHealth literacy efficacy, computer and web knowledge, and basic computer and web operation skills (P<.001 for all 3 cases).

Conclusions: Older adults’ eHealth literacy can be improved through effective intervention, and the IL or CL condition may have little effect on short-term outcomes. However, to maintain long-term benefits, it may be best to learn collaboratively with others who have similar previous computer experience. eHealth literacy is multidimensional, with some components retained better over time. Findings suggest a need for resources to provide continuous training or periodic boosting to maintain intervention gains.
eHealth literacy; digital literacy; older adults; eHealth; aging; web-based information; health information

Introduction

Background

Health literacy is defined as the degree to which individuals have the capacity to obtain, process, and understand the basic health information and services needed to make appropriate health decisions [1]. Health literacy is important as those with below-basic levels of health literacy are at greater risk of lagging their peers across several health outcomes [1]. Older age is strongly associated with lower health literacy [2]. In fact, of all adult groups in the United States, the older adult population has the lowest health literacy level—a critical issue given the rapidly growing US older adult population [3-5]. Older adults often have multiple chronic health conditions that increase their interactions with health care providers, which in turn increases their need for sufficient health literacy [6]. However, only 3% of older adults in the United States have proficient health literacy [4].

Researchers continue to assess which components are critical for effective health literacy interventions and implementation strategies for older adults. A systematic review by Walters et al [7] highlighted the increasing attention of research on health literacy interventions in recent years, with just 5 studies published before 2017 and 17 studies published up to the first quarter of 2020. This review reinforces findings from various earlier reviews showing that few interventions have determined best practices for health literacy interventions, such as whether older adults learn better in groups or as individuals [7-12].

eHealth Literacy

Health literacy research continues to evolve as the conceptualization of health literacy evolves. As information and communication technologies become integral in delivering and receiving health care, areas such as eHealth literacy have emerged [13]. In 2006, Norman and Skinner [14] promoted the concept of eHealth literacy as “the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem.” Norman [15] further pointed out that, as technology changes, so do the requirements for eHealth literacy skills. Health agencies such as the Centers for Disease Control and Prevention are increasingly providing health information on the web, making the internet an important and sometimes the main source of health information accessed via mobile phones and tablets [16].

This shift to electronic dissemination of health information has implications for health literacy interventions, suggesting that they should focus on eHealth literacy [17]. Such a focus is important as there is some evidence suggesting that older adults are interested in seeking health information on the web [18], yet older adults tend to have low digital literacy [19]. This can be addressed via eHealth literacy interventions that increase digital skills [20]. To address eHealth literacy challenges, it is essential to conceptualize health literacy as an active, dynamic process of lifelong learning [21], a process that goes beyond formal educational settings in early life and features continuous learning of new ways to find valid, reliable health information from trusted web-based resources [22]. This study is part of a series of projects that add to the health literacy literature by investigating the effectiveness of a theory-based intervention to contribute to the understanding of how different intervention strategies may affect older adults’ acquisition of eHealth literacy.

Collaborative Learning in Community Settings

Collaborative learning (CL) refers to “any instructional method in which students work together in small groups toward a common goal” [23]. CL promotes engagement for both the individual and the group as students progress through the learning process [24]. Older adults value CL with and from their peers about important health issues such as diabetes and cancer [25]. Within the context of learning to use computers, CL has been found to be effective for both learning outcomes and social development in older adults [26-28], although an earlier study [29] found that older adults performed similarly in computer learning regardless of learning individually or in pairs. In the context of eHealth literacy, CL enables opportunities to learn new health information and skills to access such information on the web [21]. Similarly, Ahmad et al [26] have suggested that CL allows older adult learners to participate with peers and interact effectively to learn digital technology.

Health-related community-based research meets older adults in their communities to provide interventions in informal settings [30]. CL for older adults typically occurs in such settings as opposed to the formal educational settings that are more typical for younger people. The Electronic Health Information for Lifelong Learners (eHiLL) studies use community settings to integrate existing public infrastructure and resources such as public libraries and senior centers [31,32]. Existing and authoritative internet health information resources developed by the National Institutes of Health (NIH) enable this type of work to be replicable and accessible to all. A systematic literature review by Kim and Xie [9] revealed that interventions combined with educational programs at the community level can encourage target groups to use web-based health resources. Affirming the importance of informal learning environments for older adults’ success in digital learning, a systematic review by Ahmad et al [26] found that, across study samples and settings, informal learning environments provided older adults with opportunities to share their experiences, options, and expectations with their peers, which encouraged them to learn.

Lifelong Learning

This study is part of the eHiLL research program, which aims to generate scientific knowledge of optimal learning conditions and strategies that can effectively and efficiently improve older adults’ learning and use of eHealth applications [20,31,33-35]. Each eHiLL study builds on previous work to examine the
effects of various learning conditions and strategies through the testing of hypotheses in rigorous theory-driven interventions. eHiLL studies are informed by social interdependence theory, which supports the superiority of CL over individualistic learning (IL) [36]. This theory emphasizes interdependence among group members by arguing that the group is a dynamic whole [36]. A meta-analysis of >300 studies has provided strong evidence that CL outperforms IL and competitive learning in postsecondary and professional settings [24]. However, less is known about CL’s effectiveness among older adult eHealth learners in informal learning settings when learning computer skills. This eHiLL study was designed to address these gaps in the literature.

Earlier eHiLL Studies and Gaps in the Literature

The first eHiLL project was a pilot study (N=172) with 1 arm to assess the effectiveness of CL with no comparison [20]. This study found evidence to suggest that CL can be a useful method for improving older adults’ eHealth literacy when paired with key elements of computer learning in older adults. The findings also indicated that social interdependence theory could be generalized beyond the younger population and formal educational settings. In a second study (N=124), we used a 2 × 2 × 2 mixed factorial design with learning method (CL and IL) and presentation (visual only and visual plus auditory) as between-subject variables and time of measurement (pre- and postintervention measurement) as the within-subject variable. The intervention, regardless of the specific combination of learning method and information presentation, was effective in improving eHealth literacy from before to after the intervention [34]. In a third study (N=146), we used a 2 × 2 mixed factorial design with learning method (CL and IL) as the between-subject variable and time of measurement (pre- and posttest measurement) as the within-subject variable to focus on CL versus IL in a new sample [21]. As in the second study, regardless of the specific learning method used, the eHealth literacy intervention significantly improved knowledge, skills, and eHealth literacy efficacy from before to after the intervention. However, CL did not differ from IL in affecting learning outcomes, suggesting that the previous widely reported advantages of CL over IL may not be easily applicable to the older population in informal settings. In all 3 studies, we used the same web-based learning modules and study protocols. Possible reasons that might have contributed to a lack of support for the superiority of CL over IL included relatively small sample sizes, underdeveloped CL strategies, potential confounding effects of various group compositions (eg, those based on sex and previous computer experience), and no follow-ups to examine potential longitudinal effects (because of a lack of resources for these pilot studies).

These earlier eHiLL studies [20,21,34], along with other studies reviewed by Ahmad et al [31], provide evidence that CL is effective for older adult populations even when using digital technologies. However, major gaps remain to be addressed, particularly with regard to longitudinal effects [20,37]. A systematic literature review by Manafo and Wong [37] found that, of 9 studies on health literacy programs for older adults, only 2 had a follow-up period, and neither of those studies reported any long-term outcomes. In addition, previous studies have identified differences in approaches to group composition in CL for older adults such that a heterogeneous group composition has been found to facilitate more successful CL than a homogeneous group composition [38,39]. Several studies have found that CL works better with either a female- or male-sex majority than in groups with equal sex composition [40,41], as well as with same-sex groups as opposed to mixed ones [41,42]. There is also some evidence suggesting that, for CL in older adults, it may be advantageous to form homogeneous groups based on previous computer experience [43]. Research is needed to address the implications of these findings in the literature.

This Study

In this study, we address the aforementioned gaps in the literature by (1) using a large randomized sample, (2) adding a 6-month follow-up to examine how gains might be maintained beyond the intervention period, (3) adding group composition based on previous computer experience as an independent variable to investigate the effects of group composition on learning outcomes, and (4) developing and implementing detailed instructions and procedures to ensure CL versus IL in the respective groups. Guided by social interdependence theory and our own previous eHiLL studies [20,21,34], in this study, we examined the research questions and hypotheses outlined in Textbox 1.

https://aging.jmir.org/2023/1/e41809
Textbox 1. Research questions and hypotheses for this study.

Research questions (RQs)
- RQ 1
  - What are the differences between the main effects of the intervention (collaborative learning [CL] vs individualistic learning [IL]) on older adults’ eHealth literacy from pre- to posttest measurement?

- RQ 2
  - Do the effects of CL interact with those of heterogeneous versus homogeneous computer-experience group composition?

- RQ 3
  - How are the effects of CL versus IL maintained beyond the training period?

Hypotheses
- Hypothesis 1
  - CL will be more effective than IL in improving older adults’ eHealth literacy.

- Hypothesis 2
  - In the CL condition, the heterogeneous group composition (mixed users) will be more effective than either homogeneous group composition (experienced user–only and new user–only).

- Hypothesis 3
  - The effects of CL will be better maintained than those of IL.

Methods

Design
For this intervention, we used a 3 $\times$ 2 $\times$ 3 mixed factorial design, with group composition based on previous computer experience (experienced, new, and mixed) and learning method (IL and CL) as between-subject variables and time of measurement (preintervention measurement, postintervention measurement, and 6-month follow-up) as the within-subject variable.

Sample and Recruitment
Recruitment included the posting and distribution of flyers at the research sites and surrounding locations (eg, in grocery stores) as well as advertising in the research sites’ newsletters and local newspapers. Recruitment continued until the target sample size was reached. The inclusion criteria were as follows: (1) age $\geq$ 60 years, (2) ability to go to and from a research site, (3) fluency in English, and (4) interest in learning about using computers to find health information. A total of 466 older adults aged 60 to 96 years participated (mean age 70.5, SD 7.2 years for all; 70.1, SD 6.7 years for the CL group; and 70.8, SD 7.6 years for the IL group).

Research Sites
Data were collected from 8 research sites: 2 public libraries in the greater Washington, District of Columbia, area; and 1 public library, 3 senior activity centers, 1 recreation center, and 1 senior living facility in the greater Austin, Texas, area. These sites were selected as they (1) served a large population of older adults of diverse ethnicities and socioeconomic status; (2) provided free networked computers, space, and staff support to facilitate the study’s implementation; (3) were geographically convenient for potential research participants and the researchers; and (4) were accessible by car or public transportation, thus enabling us to reach a diverse range of older adults.

Ethics Approval
Before the intervention, participants signed a consent form approved by the institutional review boards of the authors’ institutions, the University of Texas at Austin (2012-05-0049) and the University of Maryland (07-0264).

Procedure
The intervention consisted of 8 two-hour sessions: 1 preintervention test (session 1), 1 postintervention test (session 8), and 6 training sessions (sessions 2-7). Participants met twice a week for 4 weeks to complete the intervention.

Participants were randomly assigned to either IL classes or CL classes, with a maximum of 8 participants per class. In each training session, participants in both classes first watched the tutorial twice with a 5-minute break in between; then, they were given a handout to perform practice activities. A facilitator was available in each training session to set up the equipment, distribute handouts, and provide immediate help whenever needed.

In the IL classes, participants wore headphones and worked on their computers during the entire intervention to avoid interaction with peers. At the beginning of each session, the facilitator stated specifically that students should work independently and avoid interacting with peers. The tutorial in IL classes also reminded participants to learn and perform the activities independently throughout the session. Participants...
were encouraged to ask the facilitator for help whenever they had any questions.

In CL classes, to encourage collaboration, we asked groups of 2 or 3 participants to share a computer by using a multiheadphone splitter during the entire intervention. In this way, all members in a group could proceed at the same pace, and different groups would not interfere with each other. At the beginning of each session, the facilitator stressed that students in each group should learn together and work with their peers to perform the practice activities. The tutorial for the CL classes provided clear instructions throughout the session to encourage collaboration—for example, by taking turns or with group discussions and reflections. Multimedia Appendices 1 to 6 provide examples of IL and CL instructions as shown on participants’ computer screens.

**Instructional Materials**

The instructional materials consisted of a series of web-based interactive tutorials developed for this study. The curriculum in the tutorials was guided by “Helping Older Adults Search for Health Information Online: A Toolkit for Trainers,” developed by the National Institute on Aging of the NIH. This free toolkit [44] is designed to improve older adults’ ability to find health information on 2 NIH websites: NIHSeniorHealth and MedlinePlus. The toolkit contains 9 modules: module 1 focuses on computer and internet basics, modules 2 to 5 introduce NIHSeniorHealth, modules 6 to 8 introduce MedlinePlus, and module 9 focuses specifically on improving one’s ability to appraise health information. As the NIHSeniorHealth website was being retired at the time of this study, we adapted the content of modules 1 and 6 to 9 to make each module fit a 2-hour training session (Table 1). We then developed 10 web-based interactive tutorials based on the 5 learning modules using Adobe Captivate (Adobe Inc.): 5 for IL classes and 5 for CL classes. Specific instructions and activities were developed to ensure CL versus IL. The differences between the 2 tutorials are summarized in Table 2.

<table>
<thead>
<tr>
<th>Session number</th>
<th>Module number</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Session 1</td>
<td>Module 1</td>
<td>Basic computer and internet terms</td>
</tr>
<tr>
<td>Session 2</td>
<td>Module 6</td>
<td>Introduction to MedlinePlus.gov and search for health topics on MedlinePlus.gov</td>
</tr>
<tr>
<td>Session 3</td>
<td>Module 7</td>
<td>Use of “Drugs and Supplement” on MedlinePlus.gov</td>
</tr>
<tr>
<td>Session 4</td>
<td>Module 8</td>
<td>How to find news, physicians, and hospitals and use multimedia on MedlinePlus.gov</td>
</tr>
<tr>
<td>Session 5</td>
<td>Module 8</td>
<td>How to find news, physicians, and hospitals and use multimedia on MedlinePlus.gov</td>
</tr>
<tr>
<td>Session 6</td>
<td>Module 9</td>
<td>How to identify the quality of health information on the internet</td>
</tr>
</tbody>
</table>
Table 2. Differences between the individualistic learning (IL) and collaborative learning (CL) tutorials.

<table>
<thead>
<tr>
<th></th>
<th>IL</th>
<th>CL</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the beginning of each tutorial</td>
<td>The tutorial provides visual instructions and the following audio instructions reminding the students to work independently: “During today’s lesson, you will work individually. This will include activities where we ask you to reflect on your own about what you have learnt. Please do not consult your fellow learners during this lesson. If you have any questions, consult the facilitator and they will answer any questions or concerns you might have.”</td>
<td>The tutorial provides visual instructions and the following audio instructions about how to work together: “During today’s lesson, you will work together with your group members to learn new skills and review the materials. Take turns completing the practice activities and moving the tutorials. If a group member has any difficulty, feel free to provide assistance. Think of yourself as a team that works together to help improve each other’s learning.”</td>
</tr>
<tr>
<td>Before performing each practice activity</td>
<td>The tutorial provides audio instructions to remind students to perform the practice activity individually, for example, “Now you are going to work individually to master the terms you just learnt.”</td>
<td>The tutorial provides audio instructions to remind students to work together to complete the practice activity, for example, “Now you are going to work together to practice what you just learnt” or “Take the next few minutes to work together to follow the instructions on the screen to open the quiz on germs and hygiene. Each partner should take turns operating the tutorial. If you encounter any difficulties, consult your group members for assistance. After each partner has a chance to practice, press the ‘Next’ button to continue.” Sometimes, the tutorial also provides visual instructions on how to practice together.</td>
</tr>
<tr>
<td>After completing each practice activity</td>
<td>The tutorial asks the students to try again or move on to the next practice.</td>
<td>The tutorial asks the students to restart the activity or try again until each group member has had a turn to practice.</td>
</tr>
<tr>
<td>At the end of each tutorial</td>
<td>The students review the lesson goals on their own.</td>
<td>Students review together the lesson goals covered in class. The following instruction is given: “Take the next few minutes to work together to review the following list of goals covered in today’s lesson. Click on the check box next to each goal to confirm that all group members are comfortable that they have mastered it. If anyone has any difficulty, work together to come to a solution and refer to the handout for further clarification.”</td>
</tr>
<tr>
<td>At the end of each learning goal in module 9</td>
<td>The students are reminded not to compare notes with anyone else.</td>
<td>In module 9, after students have accomplished each learning goal, they are asked to compare notes with their peers.</td>
</tr>
</tbody>
</table>

**Measures**

We used both objective and subjective measures to assess the learning outcomes or serve as control variables. The measures and data collection times are summarized in Table 3.
Table 3. Measures used and time of measurement.

<table>
<thead>
<tr>
<th>Category of measures and variable</th>
<th>Measure</th>
<th>Time&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Objective learning outcome</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge acquisition</td>
<td>Objective tests of knowledge of computer components (eg, keyboard and mouse) and the web (eg, link and scroll bar). Computer knowledge and web knowledge were each measured using 10 items; each item was scored with 1 point if answered correctly and 0 points if answered incorrectly (scoring range 0-20).</td>
<td>✓✓✓</td>
</tr>
</tbody>
</table>
| Skill acquisition                | 3 procedural tests required participants to carry out specific tasks on networked computers:  
  - Basic computer and web operation: participants performed 12 basic operations on the computer (eg, open a web browser and go to a website). Each task was scored with 1 point if performed correctly or 0 points if done incorrectly (scoring range 0-12).  
  - Information seeking: participants received 4 scenarios in which they were asked to find information about specific health topics on the internet (eg, find at least two treatments for breast cancer). Each scenario was scored from 0 to 2 (0 if no relevant information was found, 1 if some but not all the required information was found, and 2 if all the required information was found; scoring range 0-8).  
  - Website evaluation: participants were asked to visit and evaluate the reliability of 8 health information websites. Evaluations were recorded as “Yes” if a website was reliable, “No” if a website was not reliable, and “Can’t decide” if the reliability of a website was unknown. Each website was scored with 1 if the evaluation result was correct or 0 if the evaluation result was incorrect or “Can’t decide” (scoring range 0-8). | ✓✓✓              |
| eHealth literacy                 | The 8-item eHealth literacy scale [14], which measures self-perceived skills and comfort with using IT for health information and decision-making. Items are scored on a 5-point Likert scale; higher scores indicate higher eHealth literacy efficacy (scoring range 8-40; Cronbach α=.89-.97, with good test-retest reliability) [15]. | ✓✓✓              |
| **Previous experience**          |                                                                         |                  |
| Previous experience with computers and the internet | 6 items, 4 of which measured the duration and frequency of previous computer and internet use. Example question: “How long have you been using a computer?” In total, 2 items measured previous computer class experience. Example: “Have you taken our computer class previously?” | ✓                |
| **Control variables**            |                                                                         |                  |
| Familiarity with peers in the same class | If and how participants may be related to or familiar with others in the same experimental condition (eg, spouse, sibling, friend, or acquaintance) | ✓                |
| Standard health literacy test    | S-TOFHLA<sup>b</sup>; 2 subscales with 36 questions; scoring range 0 to 36; Cronbach α=.97 (reading) and .68 (numeracy) [45] | ✓                |
| Demographic and health factors   | Age, sex, education, health, race and ethnicity, income, and primary language | ✓                |
| **Postintervention questionnaire** |                                                                         |                  |
| Satisfaction                     | How would you evaluate your entire experience in this computer class? (“Extremely dissatisfied,” “Dissatisfied,” “Neither satisfied nor dissatisfied,” “Satisfied,” and “Extremely satisfied”) | ✓                |
| Whom did participants learn from? | During the past 4 weeks, while in class, from whom did you learn about computers? (“Peer student(s),” “Mostly the peer student(s),” “The tutorial and peer(s) equally,” “Mostly the tutorial,” and “The tutorial”) | ✓                |
| Interaction with peers           | During the past 4 weeks, how much in-class interaction have you had with your peer(s)? (“None,” “A little,” “Some,” “A lot,” and “Extensive”) | ✓                |

<sup>a</sup>1: before the intervention; 2: after the intervention; 3: 6-month follow-up.

<sup>b</sup>S-TOFHLA: Short Test of Functional Health Literacy in Adults.
Data Analysis

Trained graduate research assistants entered the data into SPSS (version 27.0; IBM Corp) for Windows, with the principal investigator monitoring data entry and cleaning by reviewing a random 10% of the data records. Before inferential analysis, the data were evaluated for accuracy, missing data, out-of-range values, and violation of the statistical assumptions. Background variables (demographics, previous experience, and language) were examined to detect potential differences between the 2 learning condition groups. Descriptive statistics were used to provide a statistical profile of the sample, with frequencies and percentages for categorical data and means and SDs for continuous data.

Mann-Whitney U tests and 2-tailed t tests were conducted to assess differences between participants who completed tests at all 3 time points and those who completed only the pretest measurement. A 3 (group composition based on previous computer experience: experienced, new, and mixed) × 2 (learning condition: IL vs CL) × 3 (time of measurement: pretest measurement, posttest measurement, and 6-month follow-up) mixed between-within univariate analysis of covariance was conducted on each of the dependent variables individually; the results for each outcome were of direct interest.

Using the 4 computer and internet experience variables, both factor analysis and cluster analysis were conducted. The factor analysis yielded one strong factor (eigenvalue 3.38 vs 0.38, 0.17, and 0.08), implying that the 4 variables are strongly related and could be used to define a continuum of computer and internet use that individuals have scores on. By contrast, the cluster analysis yielded a clean separation of 2-cluster solutions, which is characterized by mean comparisons that ranged between 1.28-1.95 (cluster 2) versus 4.38-5.08 (cluster 1). Cluster 1 is a group that has been using the computer and internet for 3 or more years and uses it at least weekly, if not more frequently. Cluster 2 is a group that has been using the computer or internet for less than a year and who typically access it less than once a month. This computer and internet familiarity dichotomous variable was used to further categorize the groups into 3 groups for group composition based on prior computer experience. The first grouping comprised of groups with <30% of participants being experienced (which we defined as the “new” user group composition in all subsequent analyses; 14/92, 15%). The second grouping comprised of groups with 30% to 70% of participants being experienced (the “mixed” group composition; 48/92, 52%). The third grouping comprised of groups with >70% of participants being experienced (the “experienced” group composition; 30/92, 33%).

The main outcome variables of interest were eHealth literacy efficacy, computer and web knowledge, and skill acquisition (3 measures: basic computer and web operation skills, information-seeking skills, and website evaluation skills). The Short Test of Functional Health Literacy in Adults (S-TOFHLA) was included as a covariate, as opposed to an outcome variable, as the intervention was not focused on the learning of outcomes measured by the S-TOFHLA. The S-TOFHLA was significantly correlated with all 5 outcomes, ranging from 0.11 (eHealth literacy efficacy) to 0.52 (computer and web knowledge).

To test the specific hypotheses of this study, we focused our analyses on the main effects of learning condition and on interactions between learning condition and previous computer experience. The main effects of previous computer experience were not a major focus as it is already well documented that previous computer experience is predictive of older adults’ computer adoption and use [46-48]. Given the expected interactions, tests of simple effects within specific levels of the design were likely [49], such as those assessing the differential impact of learning condition within the experienced, new, and mixed levels of previous computer experience.

The models were conducted with and without control variables. A consistent pattern of seeing no differences with and without control variables was observed. The control variables included age, sex, education, health status, race and ethnicity, income, and primary language. The inclusion of these control variables could increase the statistical power of the design given that the variance in outcomes would likely be due, in part, to variability in one or more of these variables. Tests of the main effects were conducted in the absence of interactions involving the main effect variables. The resulting effect size estimates were calculated to compare the magnitude of change for the different types of dependent variables and between time points using $\eta_p^2$ [50].

Results

Participants

Participants’ demographics and other background information are summarized in Table 4. Participants were randomized into the IL (233/466, 50%) or CL (233/466, 50%) group. Chi-square and t tests showed no significant differences in baseline characteristics between the IL and CL groups except in English as participants’ primary language ($\chi^2$=5.6; P=.02); English was the primary language of more participants in the IL group than in the CL group (211/233, 90.6% vs 194/233, 83.3%). A total of 85.4% (398/466) of the original sample completed the postintervention assessment, and 41% (191/466) completed the 6-month follow-up assessment.
Table 4. Participant characteristics (N=466).

<table>
<thead>
<tr>
<th></th>
<th>All, n (%)</th>
<th>IL(^a) group (n=233), n (%)</th>
<th>CL(^b) group (n=233), n (%)</th>
<th>(P) value for chi-square or t test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex (female)</strong></td>
<td>312 (67)</td>
<td>154 (66.1)</td>
<td>158 (67.8)</td>
<td>.69</td>
</tr>
<tr>
<td><strong>Race and ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>188 (40.3)</td>
<td>81 (34.8)</td>
<td>107 (45.9)</td>
<td>.10</td>
</tr>
<tr>
<td>White</td>
<td>153 (32.8)</td>
<td>84 (36.1)</td>
<td>69 (29.6)</td>
<td></td>
</tr>
<tr>
<td>Latino</td>
<td>88 (18.9)</td>
<td>49 (21)</td>
<td>39 (16.7)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>37 (7.9)</td>
<td>19 (8.2)</td>
<td>18 (7.7)</td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
<td>.99</td>
</tr>
<tr>
<td>Lower than high school</td>
<td>52 (11.2)</td>
<td>27 (11.6)</td>
<td>25 (10.7)</td>
<td></td>
</tr>
<tr>
<td>High school</td>
<td>116 (24.9)</td>
<td>58 (24.9)</td>
<td>58 (24.9)</td>
<td></td>
</tr>
<tr>
<td>Some college</td>
<td>159 (34.1)</td>
<td>80 (34.3)</td>
<td>79 (33.9)</td>
<td></td>
</tr>
<tr>
<td>Bachelor’s degree or higher</td>
<td>138 (29.6)</td>
<td>68 (29.2)</td>
<td>70 (30)</td>
<td></td>
</tr>
<tr>
<td><strong>Yearly household income (US $)</strong></td>
<td></td>
<td></td>
<td></td>
<td>.12</td>
</tr>
<tr>
<td>&lt;20,000</td>
<td>163 (35)</td>
<td>88 (37.8)</td>
<td>75 (32.2)</td>
<td></td>
</tr>
<tr>
<td>20,000-29,000</td>
<td>86 (18.5)</td>
<td>38 (16.3)</td>
<td>48 (20.6)</td>
<td></td>
</tr>
<tr>
<td>30,000-39,000</td>
<td>48 (10.3)</td>
<td>30 (12.9)</td>
<td>18 (7.7)</td>
<td></td>
</tr>
<tr>
<td>40,000-99,000</td>
<td>91 (19.5)</td>
<td>37 (15.9)</td>
<td>54 (23.2)</td>
<td></td>
</tr>
<tr>
<td>≥100,000</td>
<td>9 (1.9)</td>
<td>4 (1.7)</td>
<td>5 (2.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Native English speaker (yes)</strong></td>
<td></td>
<td></td>
<td></td>
<td>.02</td>
</tr>
<tr>
<td>Health status (excellent and very good)</td>
<td>123 (26.4)</td>
<td>65 (27.9)</td>
<td>58 (24.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency of computer use</strong></td>
<td></td>
<td></td>
<td></td>
<td>.84</td>
</tr>
<tr>
<td>Never</td>
<td>151 (32.4)</td>
<td>75 (32.2)</td>
<td>76 (32.6)</td>
<td></td>
</tr>
<tr>
<td>Less than once a month</td>
<td>54 (11.6)</td>
<td>29 (12.4)</td>
<td>25 (10.7)</td>
<td></td>
</tr>
<tr>
<td>More than once a month</td>
<td>35 (7.5)</td>
<td>18 (7.7)</td>
<td>17 (7.3)</td>
<td></td>
</tr>
<tr>
<td>Once a week</td>
<td>47 (10.1)</td>
<td>20 (8.6)</td>
<td>27 (11.6)</td>
<td></td>
</tr>
<tr>
<td>Every 2-3 days</td>
<td>86 (18.5)</td>
<td>41 (17.6)</td>
<td>45 (19.3)</td>
<td></td>
</tr>
<tr>
<td>Every day</td>
<td>93 (20)</td>
<td>50 (21.5)</td>
<td>43 (18.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Length of computer use (years)</strong></td>
<td></td>
<td></td>
<td></td>
<td>.86</td>
</tr>
<tr>
<td>Never</td>
<td>130 (27.9)</td>
<td>67 (28.8)</td>
<td>63 (27)</td>
<td></td>
</tr>
<tr>
<td>&lt;1</td>
<td>91 (19.5)</td>
<td>42 (18)</td>
<td>49 (21)</td>
<td></td>
</tr>
<tr>
<td>1-3</td>
<td>51 (10.9)</td>
<td>27 (11.6)</td>
<td>24 (10.3)</td>
<td></td>
</tr>
<tr>
<td>3-5</td>
<td>32 (6.9)</td>
<td>18 (7.7)</td>
<td>14 (6)</td>
<td></td>
</tr>
<tr>
<td>5-10</td>
<td>64 (13.7)</td>
<td>29 (12.4)</td>
<td>35 (15)</td>
<td></td>
</tr>
<tr>
<td>&gt;10</td>
<td>96 (20.6)</td>
<td>49 (21)</td>
<td>47 (20.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Frequency of internet use</strong></td>
<td></td>
<td></td>
<td></td>
<td>.98</td>
</tr>
<tr>
<td>Never</td>
<td>196 (42.1)</td>
<td>98 (42.1)</td>
<td>98 (42.1)</td>
<td></td>
</tr>
<tr>
<td>Less than once a month</td>
<td>53 (11.4)</td>
<td>27 (11.6)</td>
<td>26 (11.2)</td>
<td></td>
</tr>
<tr>
<td>More than once a month</td>
<td>27 (5.8)</td>
<td>13 (5.6)</td>
<td>14 (6)</td>
<td></td>
</tr>
<tr>
<td>Once a week</td>
<td>36 (7.7)</td>
<td>17 (7.3)</td>
<td>19 (8.2)</td>
<td></td>
</tr>
<tr>
<td>Every 2-3 days</td>
<td>72 (15.5)</td>
<td>34 (14.6)</td>
<td>38 (16.3)</td>
<td></td>
</tr>
<tr>
<td>Every day</td>
<td>81 (17.4)</td>
<td>43 (18.5)</td>
<td>38 (16.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Length of internet use (years)</strong></td>
<td></td>
<td></td>
<td></td>
<td>.84</td>
</tr>
<tr>
<td>Never</td>
<td>185 (39.7)</td>
<td>93 (39.9)</td>
<td>92 (39.5)</td>
<td></td>
</tr>
</tbody>
</table>
### Participants Who Completed All 3 Time Points Versus Those Who Did Not

In t tests and Mann-Whitney U tests, no significant differences were found for baseline age ($P = .623$), education ($P = .052$), health ($P = .090$), language ($P = .705$), income ($P = .893$), computer and web knowledge ($P = .453$), basic computer and web operation ($P = .731$), and website evaluation ($P = .929$) between participants who completed all 3 time points and those who completed only the pretest measurement. There were no statistically significant differences in dropout rates between the IL and CL groups from baseline to postintervention measurement ($P = .660$) and from baseline to 6-month follow-up ($P = .778$).

Significant differences were found between those who completed all 3 time points and those who did not for sex ($P = .009$), race and ethnicity ($P < .001$), baseline computer use length ($P = .001$), internet use length ($P < .001$), computer use frequency ($P < .001$), internet use frequency ($P < .001$), eHealth literacy efficacy ($P < .001$), health literacy ($P = .04$), and information-seeking skills ($P = .02$). In comparison with participants who completed only the pretest measurement, there was a higher proportion of women (62% vs 74%), a lower proportion of African American individuals (51% vs 26%), and a higher proportion of those who reported more frequent and longer length of computer (17% vs 25%) or internet use (8% vs 17%) at baseline among participants who completed all 3 time points. Participants who completed all 3 time points also reported significantly higher scores on the eHealth literacy efficacy scale (mean difference=1.56), S-TOFHLA (mean difference=2.52), and information-seeking skill test (mean difference=1.27) at baseline.

---

### Tests of Hypotheses

Examination of general linear models revealed 1 statistically significant model of interest (Table 5). The model with basic computer and web operation skills as the outcome resulted in a significant interaction that supported hypothesis 3. There was a significant interaction between learning condition and previous computer experience ($F_{2,55} = 3.69$; $P = .03$). Simple effects were examined to decompose interaction results. Specifically, from postintervention measurement to 6-month follow-up, within the IL group, on average, being in a group with little or no previous computer experience (mean = −0.59, SE 0.54) was more beneficial for retaining computer skills than being in a group with medium previous computer experience (mean = −1.06, SE 0.25) or high previous computer experience (mean = −1.65, SE 0.35). In comparison, in the CL group, on average, being in a group with high previous computer experience (mean = −0.60, SE 0.35) was more beneficial for retaining computer skills than being in a group with medium previous computer experience (mean = −0.64, SE 0.21) or little to no previous computer experience (mean = −2.40, SE 0.82). Hypothesis 3 was partially supported; that is, the effects of CL were better maintained than those of IL for individuals in certain groups. Specifically, for people with little to no previous experience, it may be better to learn individually, whereas for people with more previous experience, it may be better to learn collaboratively. These results were specific to computer and web operation skills and maintenance of those skills at 6 months after the intervention.

No statistically significant differences were found in models examining the interactions between learning condition and previous computer experience for each of the following outcome measures: eHealth literacy efficacy, computer and web knowledge, information-seeking skills, and website evaluation skills (results not shown; available from the authors upon request). Hypotheses 1 and 2 were not supported.

---

<table>
<thead>
<tr>
<th>All, n (%)</th>
<th>IL&lt;sup&gt;a&lt;/sup&gt; group (n=233), n (%)</th>
<th>CL&lt;sup&gt;b&lt;/sup&gt; group (n=233), n (%)</th>
<th>P value for chi-square or t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td>78 (16.7)</td>
<td>35 (15)</td>
<td>43 (18.5)</td>
</tr>
<tr>
<td>1-3</td>
<td>50 (10.7)</td>
<td>27 (11.6)</td>
<td>23 (9.9)</td>
</tr>
<tr>
<td>3-5</td>
<td>35 (7.5)</td>
<td>18 (7.7)</td>
<td>17 (7.3)</td>
</tr>
<tr>
<td>5-10</td>
<td>62 (13.3)</td>
<td>29 (12.4)</td>
<td>17 (7.3)</td>
</tr>
<tr>
<td>&gt;10</td>
<td>56 (12)</td>
<td>31 (13.3)</td>
<td>33 (14.2)</td>
</tr>
<tr>
<td>Familiar with other participants (yes)</td>
<td>126 (27)</td>
<td>68 (29.2)</td>
<td>58 (24.9)</td>
</tr>
</tbody>
</table>

<sup>a</sup> IL: individualistic learning.
<sup>b</sup> CL: collaborative learning.
Table 5. General linear model results for retaining basic computer and web operation skills from postintervention measurement to 6-month follow-up.

<table>
<thead>
<tr>
<th>Basic computer and web operation</th>
<th>Wald F test (df)</th>
<th>P value^a</th>
</tr>
</thead>
<tbody>
<tr>
<td>IL^b or CL^c learning condition</td>
<td>0.09 (1)</td>
<td>.77</td>
</tr>
<tr>
<td>Computer familiarity</td>
<td>6.44 (1)</td>
<td>.01</td>
</tr>
<tr>
<td>Computer experience grouping</td>
<td>0.94 (2)</td>
<td>.40</td>
</tr>
<tr>
<td>IL or CL × computer familiarity</td>
<td>2.14 (1)</td>
<td>.15</td>
</tr>
<tr>
<td>IL or CL × previous experience grouping</td>
<td>3.69 (2)</td>
<td>.03</td>
</tr>
<tr>
<td>Computer familiarity × experience grouping</td>
<td>0.42 (2)</td>
<td>.66</td>
</tr>
<tr>
<td>IL or CL × computer familiarity × experience grouping</td>
<td>2.04 (2)</td>
<td>.14</td>
</tr>
</tbody>
</table>

^aα=.05.
^bIL: individualistic learning.
^cCL: collaborative learning.

Main Effects

Univariate repeated-measure analyses revealed statistically significant differences between pretest measurement, posttest measurement, and 6-month follow-up for all 5 outcome measures (Table 6).

Follow-up comparison tests for these 5 outcome measures showed statistically significant improvements in mean scores from pre- to posttest measurement (P<.001 for all 5 cases).

Table 6. Means, F test results, and effect sizes.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Pretest measurement, mean (SD)</th>
<th>Posttest measurement, mean (SD)</th>
<th>6-month follow-up, mean (SD)</th>
<th>F test (df)^a</th>
<th>η_p^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>eHealth literacy efficacy</td>
<td>19.86 (8.08)</td>
<td>33.37 (4.68)</td>
<td>32.06 (5.93)</td>
<td>373.82 (2)</td>
<td>0.676</td>
</tr>
<tr>
<td>Computer and web knowledge</td>
<td>12.59 (4.69)</td>
<td>15.66 (3.30)</td>
<td>12.59 (4.69)</td>
<td>89.60 (2)</td>
<td>0.334</td>
</tr>
<tr>
<td>Basic computer and web operation</td>
<td>6.29 (3.75)</td>
<td>9.44 (2.62)</td>
<td>6.29 (3.75)</td>
<td>167.92 (2)</td>
<td>0.484</td>
</tr>
<tr>
<td>Information-seeking skills</td>
<td>2.18 (2.63)</td>
<td>4.32 (2.56)</td>
<td>2.18 (2.63)</td>
<td>52.92 (2)</td>
<td>0.228</td>
</tr>
<tr>
<td>Website evaluation skills</td>
<td>4.02 (2.00)</td>
<td>5.04 (1.89)</td>
<td>4.02 (2.00)</td>
<td>35.80 (2)</td>
<td>0.167</td>
</tr>
</tbody>
</table>

^aP value for all F test values is <.001.

Postintervention Questions

There were no significant differences in participants’ satisfaction between the CL (100% satisfaction) and IL (99% satisfaction) groups (N=382, χ^2=1.1; P=.29). Overall, participants in both groups had satisfactory experiences with the intervention.

There were significant differences between the CL and IL groups for learning with peers versus tutorials (N=382, χ^2=29.2; P<.001) and for the amount of in-class interaction with peers (N=382, χ^2=84.3; P<.001). Demonstrating validity, individuals in the CL group reported learning from a combination of peers and the tutorial, whereas individuals in the IL group reported learning "exclusively" from the tutorial. Similarly, individuals in the IL group reported low interaction with peers, whereas individuals in the CL group reported high interaction with peers.

Discussion

Principal Findings

Older adults are less likely than younger adults to use the internet for tasks such as receiving test results, renewing prescriptions, and scheduling appointments, in part because of a low level of digital competence [51]. The COVID-19 pandemic has made accessing health information and services on the web a near necessity [52,53], exacerbating the need for eHealth literacy. Effective interventions are much needed to ensure the digital inclusion of older adults during and after the pandemic. This study’s principal findings are as follows: (1) there are no major differences in older adults’ eHealth literacy learning with regard to learning collaboratively versus individually when measured immediately after the intervention; (2) however, to maintain long-term benefits, it may be best to learn collaboratively with others that have similar previous computer experience; (3) regardless of the IL or CL method,
this intervention was effective for increasing eHealth literacy in older adults; and (4) conducting periodic follow-up training (ie, booster sessions) may be important for improving the maintenance of gains over time. It is important to note that our sample included a large proportion of African American (188/466, 40.3%) and Latino (88/466, 18.9%) participants. The literature on eHealth interventions over the past 2 decades documents the lack of studies with racial and ethnic minority samples as well as the continued need to include these groups in studies [54-57]. This study’s inclusion of a substantial proportion of participants from racial and ethnic minorities strengthens the evidence that our eHiLL intervention works for older adults from diverse groups.

**CL Versus IL**

In this study, we compared the impact of CL versus IL on older adults’ learning of eHealth literacy and digital skills. Our data did not provide support for hypotheses 1 and 2. However, hypothesis 3 was partially supported. For participants in a group with medium or high previous computer experience, learning was maintained better at the 6-month follow-up in the CL condition, whereas in the IL condition, learning was maintained better for those in a group with low previous computer experience. Thus, previous computer experience may mediate the relationship between learning outcomes and learning methods.

We did not find any statistically significant differences from pre- to posttest measurement in the effects of CL versus IL on any of the outcome measures. This finding aligns with a previous study that used an earlier iteration of the intervention to test IL and CL [20]. The 5 principles of CL might shed light on why [36]. These principles are as follows: (1) to ensure that students understand that their scores are dependent on both their individual and group members’ performances (eg, by giving bonus points to each student if all members of the group score at a certain percentage or higher on a test); (2) to structure individual accountability so that each student’s individual contribution is assessed (eg, by giving individual tests, having each student explain their contribution to the group, or observing group interactions and documenting each student’s contributions); (3) to ensure that students help, assist, support, encourage, and praise one another’s learning efforts through face-to-face interactions; (4) to ensure that students have needed social skills (eg, communication and leadership) and use them properly in the group; and (5) to ensure that students have adequate time to engage in group interactions, reflect on what works and what does not, and make decisions about what actions to continue or change.

However, these principles have been developed for formal educational settings, and they are less applicable to informal settings [24,36]. Therefore, in this study, not all the principles were included. For example, the literature suggests that it is important to build dependency and accountability, which would work in formal educational settings [36]. In this study’s context, individual success was not designed to be dependent on group success. Furthermore, this study, by nature, could not hold individual group members accountable for group success in any formal way. Each participant’s individual contribution was not formally assessed, but it is plausible that having each participant explain their contribution to the group or observing group interactions and documenting participants’ contributions might create a stronger sense of accountability within the group. Future research should assess creative ways to ensure dependency and accountability among older adult learners in informal settings.

The literature has found CL to work in informal settings with older adults [26], although this has not been supported with regard to computer training from pre- to posttest measurement [20,21,34]. Previous eHiLL studies [20,21,34] did not conduct follow-ups, so there was no evidence on the longitudinal effects of CL. In this study, which included a follow-up, CL did work better under certain conditions over the longer term.

Computer learning is more challenging than other subjects in informal learning [58]. An additional challenge is that CL research generally does not provide detailed instructions to ensure collaboration [59]. Therefore, in this study, we provided more detailed instructions for collaboration as the participants progressed through the modules. The participants’ responses indicated that they did learn either collaboratively or individually in accordance with their group assignment; it is unlikely that our CL strategies were insufficient in soliciting CL.

**Group Composition**

Similar to hypothesis 1, hypothesis 2 was rejected, and no statistically significant differences were found between either learning condition and group composition. However, the partial support for hypothesis 3 may provide some insights into how group composition may affect learning outcomes over the longer term. Group composition appears to matter depending on the characteristic used to group participants. In this study, there were no differences between the CL and IL groups with regard to the familiarity of the participants within their groups. However, the literature has documented familiarity with group partners as a factor that may contribute to increased collaboration [40,41,60]. The relative benefits of CL versus IL among older adults—with familiar or unfamiliar partners—require further examination.

Our findings do indicate that grouping by previous computer experience may be particularly important for older adults’ learning over the longer term. This study’s findings are complemented by those from an earlier study with previous versions of the tutorial [20]. On the basis of information from the previous study, the differences in participants’ previous computer experience might have at least partially affected their learning experience and outcomes. Xie [20] found that more experienced learners sometimes became frustrated and felt that they were not making the best use of their time when an instructor had to stop frequently to help less experienced peers keep up with basic procedures (eg, manipulating a mouse). The opposite happened as well: less experienced learners sometimes became embarrassed and frustrated and at times were intimidated by more experienced peers. These observations, in addition to guidance from the literature [43], support the change in this study to separate older adults into different groups based on their previous computer experience. This study’s findings suggest that CL may be most beneficial for more experienced older adults when they are grouped with others who have similar
levels of previous computer experience. Perhaps, when group members have already obtained sufficient previous experience, they can use their collective previous experience to learn from each other [61]. In comparison, CL groups with low collective previous experience may not have sufficient combined skills and knowledge to progress effectively. A recent systematic review also suggests that knowledge level and experience seems to be the most suitable and important attribute to form educational groups because of its effects on group outcomes [62]. Thus, IL may be better over the long term for older adult learners with low previous computer experience as each individual can move at a comfortable pace and may not be embarrassed to ask for help.

Overall Impact of the eHealth Intervention

In this study, we examined the intervention’s effects on 5 outcomes: eHealth literacy efficacy, computer and web knowledge, basic computer and web operation, information-seeking skills, and website evaluation skills. Overall, the results show statistically significant improvements from before to after the intervention for all 5 outcomes ($P < .001$ in all cases). Thus, the intervention, with CL or IL, is effective in improving older adults’ eHealth literacy. Effect sizes ranged from 0.167 to 0.676, suggesting that the magnitude of improvement was large for all 5 outcomes (according to the general guidelines used to interpret values for effect sizes: 0.2 = small effect size, 0.5 = medium effect size, and $\geq 0.8$ = large effect size) [50]. These results align with previous eHiLL studies, which included 3 of the same outcome variables (computer and web knowledge, computer and web skills, and eHealth literacy) also with large effect sizes [20,21,33,34]. The consistently large effects of the intervention in different populations and contexts highlight the potential generalizability of the intervention to improve older adults’ eHealth literacy.

Longitudinal Effects

In this study, we included a follow-up at 6 months to assess how well improvements were retained. Overall, there was a decrease in scores from postintervention measurement to 6-month follow-up, with statistically significant decreases for 3 of the 5 outcomes (eHealth literacy efficacy, computer and web knowledge, and basic computer and web operation; $P < .001$ for all 3 cases). The decreases in information-seeking skills and website evaluation were not statistically significant. eHealth literacy is multidimensional, and some of its components may not be retained better than others over time. However, it is possible that a worse long-term impact might have been observed overall if a longer follow-up was used, such as 1 year. A recent study assessing cognitive training for older adults found that little or no benefit remained 1 year after intensive initial training [63]. This study’s findings suggest a need for resources to provide continuous training or periodic boosting given that benefits gained from pre- to posttest measurement dropped after 6 months. A study [64] assessing cognitive ability training with older adults that included long-term booster training (11 and 35 months after the intervention) and long-term follow-up tests (1, 3, and 5 years) found that the effects of the intervention were still present 5 years later. Further research is needed to understand how often such “booster” training is needed for this intervention to maximize resources (eg, every 1, 2, or 3 months). Another promising training component to consider for observing long-term effects might be frequent testing, which may lead to a practice-retrieval effect—there is some evidence suggesting that more frequent testing during an intervention phase is associated with long-term skill retention [65].

In addition to including the follow-up at 6 months, this study also addressed other limitations of previous eHiLL studies. We included a large sample size, a more even baseline group composition and group size because of randomization, and consistency of instructors. In earlier eHiLL studies, because of limited funding, it was not feasible to control for variation in instructors. Earlier eHiLL studies used many graduate students as instructors for the training classes, who were recruited through various mechanisms—some were part-time research assistants, some received course credits, and some were simply volunteers. These graduate students’ enthusiasm speaks to the sustainability of the training program, but from the point of view of an intervention study, individual differences among such instructors (eg, personality, teaching style, experience, time commitment, and incentive) likely introduced unnecessary confounding variation into the previous studies. Therefore, in this study, we provided full-time support for a few instructors to minimize the potential impact of this factor. In short, compared with the earlier studies, this study provides stronger support for the effectiveness of the intervention overall and its various components. This evidence should enable other researchers to replicate this work using other samples, settings, learning conditions, or delivery methods.

Strengths and Limitations

First, this study’s large sample size ensured sufficient statistical power for the findings; however, the sample may not be representative of the older adult population in general. Second, differential dropout by race and ethnicity, sex, and computer experience suggests that additional tailoring is needed to promote better adherence. For example, He et al [66] found evidence that machine learning–based approaches provided with individual characteristics and previous intervention data can provide useful information for predicting adherence, providing initial clues as to who to target with adherence support strategies and when to provide support. Further assessment of these types of innovations will be critical to strengthen an intervention’s ability to support those at risk of poor adherence. Other researchers should replicate this study in other communities with different samples of older adults, which would help further strengthen the eHiLL intervention’s generalizability.

Third, an inevitable limitation of any technology-related intervention is that technology evolves rapidly, rendering some intervention components (and corresponding outcome measures) outdated. Continuous updating of intervention components and outcome measures will be necessary for future interventions (eg, to be based on mobile devices and apps and voice-based web search enabled by new technology). Our findings suggest that eHealth literacy is multidimensional and that some of its components (eg, the ability to search for relevant information on the web to solve specific tasks, as measured in our information-seeking skill testing, and assess the quality of health information-seeking skill testing, and assess the quality of health
information on websites, as measured in our website evaluation test) might be better retained than others (eg, eHealth literacy efficacy, computer and web knowledge, and basic computer and web operation) over time. This phenomenon is worth future systematic investigation, which might lead to the development of more granular interventions targeting specific dimensions or components of eHealth literacy.

**Implications and Directions for Future Research**

Given the context of this work in the larger program of work that has been carried out over a decade, there is strong evidence to suggest that older adults can increase their eHealth literacy via various learning conditions. This is important as increasing eHealth literacy for older adults can have substantial positive impacts on their health management in several ways. For example, those who are eHealth literate can take advantage of the many technologies that allow health care providers to monitor one’s health remotely in real time. Older adults with diabetes may upload food logs, blood sugar levels, and drugs taken that providers can check daily and provide feedback on [67]. Also relevant for older adults are tools that can detect changes in daily activities, such as falls, and devices that send notifications to remind one to exercise or take drugs [67]. These technologies are only useful if one has the eHealth literacy to use them.

In addition, being able to incorporate eHealth into the management of their health can possibly help reduce other stressors. For example, knowing how to navigate a web-based health portal can help save time by allowing older adults to communicate with their providers through web-based messages as opposed to waiting on the phone just to pass their message along to someone who is not their physician. This could possibly reduce the stress associated with missing a phone call from their physician’s office, knowing that they can check their message at any time as soon as it is available. Similarly, older adults can save time by making an appointment with their physician on the web. As telehealth becomes more common, when appropriate, older adults can take appointments in the comfort of their own homes, which can help reduce stress related to finding a date and time that works best for them to find transportation. eHealth has the potential to increase the health and well-being of older adults, and increasing eHealth literacy is one step toward helping them do so.

Further research should also examine how often booster training may be needed to maximize resources. Scalability should be of interest for future studies to assess the mass-scale impact this intervention can have. Future studies are being planned to assess the intervention’s effectiveness with remote learning or hybrid modalities that may be better suited to a world coping with the COVID-19 pandemic. The finding that the intervention is effective with remote learning modalities will help strengthen the evidence that this intervention has the potential to be scalable at a national level. Finally, in this study, previous-experience group composition was a key factor; however, future research could assess if there are other, more effective group composition possibilities, such as groups based on self-assessed technology proficiency (ie, computer, mobile device, and networking proficiency). Tools assessing these proficiency levels [68-70] can be incorporated to assess whether composing groups based on overall high and low technology proficiency leads to more effective training, as suggested by the interactions found between group composition and learning condition.

**Acknowledgments**

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**Data Availability**

The data sets generated and analyzed during this study are available from the corresponding author upon reasonable request.

**Conflicts of Interest**

None declared.

Multimedia Appendix 1

Instructions at the beginning of the individualistic learning (IL) tutorial.

[PNG File, 75 KB - aging_v6i1e41809_app1.png ]

Multimedia Appendix 2

Instructions at the beginning of the collaborative learning (CL) tutorial.

[PNG File, 68 KB - aging_v6i1e41809_app2.png ]

Multimedia Appendix 3

Example of Instructions before practice activities in the collaborative learning (CL) tutorial (Step 1, Module 2).
References


The Impact of Health Information Exchange on In-Hospital and Postdischarge Mortality in Older Adults with Alzheimer Disease Readmitted to a Different Hospital Within 30 Days of Discharge: Cohort Study of Medicare Beneficiaries

Sara Turbow1,2, MD, MPH; Camille P Vaughan3,4, MD, MS; Steven D Culler5, PhD; Kenneth W Hepburn6, PhD; Kimberly J Rask7, MD, PhD; Molly M Perkins3, MA, PhD; Carolyn K Clevenger6, DNP, RN, GNP-BC, AGPCNP-BC; Mohammed K Ali2,8, MD, MSc, MBA

1Division of General Internal Medicine, Department of Medicine, Emory University School of Medicine, Atlanta, GA, United States
2Department of Family & Preventive Medicine, Emory University School of Medicine, Atlanta, GA, United States
3Division of Geriatrics & Gerontology, Department of Medicine, Emory University School of Medicine, Atlanta, GA, United States
4Birmingham/Atlanta Geriatric Research Education and Clinical Center, Department of Veterans Affairs, Atlanta, GA, United States
5Department of Health Policy and Management, Rollins School of Public Health, Emory University, Atlanta, GA, United States
6Nell Hodgson Woodruff School of Nursing, Emory University, Atlanta, GA, United States
7Alliant Health, Atlanta, GA, United States
8Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, GA, United States

Corresponding Author:
Sara Turbow, MD, MPH
Division of General Internal Medicine
Department of Medicine
Emory University School of Medicine
49 Jesse Hill Jr Dr SE
Atlanta, GA, 30303
United States
Phone: 1 404 251 8897
Email: sara.turbow@emory.edu

Abstract

Background: Although electronic health information sharing is expanding nationally, it is unclear whether electronic health information sharing improves patient outcomes, particularly for patients who are at the highest risk of communication challenges, such as older adults with Alzheimer disease.

Objective: To determine the association between hospital-level health information exchange (HIE) participation and in-hospital or postdischarge mortality among Medicare beneficiaries with Alzheimer disease or 30-day readmissions to a different hospital following an admission for one of several common conditions.

Methods: This was a cohort study of Medicare beneficiaries with Alzheimer disease who had one or more 30-day readmissions in 2018 following an initial admission for select Hospital Readmission Reduction Program conditions (acute myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, and pneumonia) or common reasons for hospitalization among older adults with Alzheimer disease (dehydration, syncope, urinary tract infection, or behavioral issues). Using unadjusted and adjusted logistic regression, we examined the association between electronic information sharing and in-hospital mortality during the readmission or mortality in the 30 days following the readmission.

Results: A total of 28,946 admission-readmission pairs were included. Beneficiaries with same-hospital readmissions were older (aged 81.1, SD 8.6 years) than beneficiaries with readmissions to different hospitals (age range 79.8-80.3 years, P < .001). Compared to admissions and readmissions to the same hospital, beneficiaries who had a readmission to a different hospital that shared an HIE with the admission hospital had 39% lower odds of dying during the readmission (adjusted odds ratio [AOR] 0.61, 95% CI 0.39-0.95). There were no differences in in-hospital mortality observed for admission-readmission pairs to different hospitals that participated in different HIEs (AOR 1.02, 95% CI 0.82-1.28) or to different hospitals where one or both hospitals...
did not participate in HIE (AOR 1.25, 95% CI 0.93-1.68), and there was no association between information sharing and postdischarge mortality.

**Conclusions:** These results indicate that information sharing between unrelated hospitals via a shared HIE may be associated with lower in-hospital, but not postdischarge, mortality for older adults with Alzheimer disease. In-hospital mortality during a readmission to a different hospital was higher if the admission and readmission hospitals participated in different HIEs or if one or both hospitals did not participate in an HIE. Limitations of this analysis include that HIE participation was measured at the hospital level, rather than at the provider level. This study provides some evidence that HIEs can improve care for vulnerable populations receiving acute care from different hospitals.

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**KEYWORDS**
readmissions; care fragmentation; health information exchange; mortality; Alzheimer disease; electronic health information; information sharing; older adults; information exchange; hospital system; health informatics

**Introduction**

Hospitalizations frequently increase during the final months of an older person’s life: two-thirds of Medicare fee-for-service beneficiaries are hospitalized in the final 6 months of life and 25% have multiple hospitalizations [1,2]. The transitions of care that occur at the end of life can lead to more readmissions [3], disruptions that may be further exacerbated by the presence of dementia. Previous work has shown that cognitive impairment is associated with decreases in both the quality of care a person receives in the hospital [4,5] and the patient’s and their caregiver’s ability to follow discharge instructions [6].

One underexamined factor that may worsen outcomes following hospitalizations in older adults is interhospital fragmentation of care, which occurs when an individual is readmitted to a hospital different than the one from which they were initially discharged. This happens in approximately 25% of all readmissions nationally and is associated with poor patient outcomes, including higher in-hospital mortality and longer lengths of stay [7-10]. Information discontinuity is one potential driver of poor outcomes in fragmented readmissions: because a patient’s medical record may not be available at the readmission hospital, the care team may be making decisions with incomplete clinical information. Health information exchanges (HIEs), data systems in which health information is electronically shared between settings of care [11,12], are a potential solution to information discontinuity and associated challenges present in fragmented readmissions.

Previous work in general adult patient populations suggests that HIE availability in the inpatient setting may be associated with fewer readmissions [13,14], particularly fragmented readmissions [15], and may be associated with a reduction in repeat laboratory and imaging tests [16-20]. If the improvement in these metrics is due to improved care coordination attributable to information obtained from the HIE, we hypothesize that these positive impacts would extend to outcomes during and following hospitalizations as well. Those with cognitive impairment may be especially vulnerable in fragmented readmissions where outside clinical information is not available. The goal of this study was to measure the association between electronic information sharing, in-hospital mortality, and mortality in the 30 days following hospital readmission among Medicare beneficiaries with Alzheimer disease (AD) initially admitted for common conditions and then readmitted to a different hospital. This information will contribute to our understanding of the impact and limitations of HIEs as tools to mitigate information discontinuity across providers. HIEs have the potential to improve care for vulnerable populations, such as older adults with AD, but this potential is limited if the 2 hospitals do not share an HIE or if one does not participate.

**Methods**

**Study Design**

We analyzed data from a longitudinal cohort of all Medicare beneficiaries in 2018 with a hospital admission for acute myocardial infarction (AMI), congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), pneumonia, dehydration, syncope, urinary tract infection (UTI), or behavioral issues and a subsequent readmission within 30 days for any reason (Figure 1). The objective of this study is to measure the association between electronic information sharing, in-hospital mortality, and mortality in the 30 days following hospital readmission to a different hospital than the beneficiary was previously discharged from.
**Data Sources**

The primary data source for this analysis was the 2018 Medicare Provider Analysis and Review (MedPar) file, which includes inpatient Medicare claims. Additional clinical characteristics were obtained from the 2018 Medicare Master Beneficiary Summary and the Chronic Conditions Segment files. Hospital characteristics were obtained from the 2018 American Hospital Association (AHA) Annual Survey [21]. HIE participation was obtained from the AHA Information Technology (IT) Supplement from 2017 and 2018 [22,23].

**Patients**

Inpatient claims from Medicare beneficiaries who had a hospital admission for AMI, CHF, COPD, pneumonia, dehydration, syncope, UTI, or behavioral issues in 2018 were obtained from the Centers for Medicare and Medicaid Services (CMS). Multimedia Appendix 1 shows the International Classification of Diseases–10 codes and diagnosis related group codes used. These conditions were chosen because they are either conditions in the Hospital Readmissions Reduction Program (HRRP) [24]—conditions, including AMI, CHF, COPD, and pneumonia, identified by the CMS as having a high risk of readmission [25]—or are common causes of hospitalization among older adults, particularly those with AD [26,27]. While the index admission was for one of the above reasons, the readmission could be for any reason. We excluded beneficiaries who did not have a readmission in the data set, claims with missing beneficiary identification numbers, and claims that represented admissions resulting from an interhospital transfer. The unit of observation was transformed from a claim to an admission-readmission pair. If a beneficiary had more than 2 hospital admissions, multiple admission-readmission pairs were created (Multimedia Appendix 2 provides examples). We then removed all admission-readmission pairs in which the time from discharge to readmission was over 30 days. The analysis was limited to beneficiaries who were listed as having a diagnosis of AD in the chronic conditions segment; this data source includes diagnoses from 1999 onward [28].

**Primary Exposure: Type of Information Sharing**

We categorized electronic information sharing based on the availability of electronic information exchange between a beneficiary’s admission and readmission hospitals based on the AHA Annual Survey and IT Supplement. The IT Supplement asks, “Please indicate your level of participation in a state, regional and/or local health information exchange or health information organization.” Answers could be “do not know,” “not operational,” “operational...we are not participating,” or “operational...we are participating and actively exchanging data.” The IT survey additionally asks, “Which of the following national health information exchange networks does your hospital participate in?” Several options are provided, including “your [electronic health record] vendor’s network which enables...”

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**Figure 1.** Sample development. AD: Alzheimer disease; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; HIE: health information exchange; MI: myocardial infarction; UTI: urinary tract infection.
exchange with vendor’s other users” and “other.” If a hospital answered “other” and provided a free-text answer to describe the HIE they participated in, their answers were recoded to be comparable between admission and readmission hospitals. If a hospital had different or missing answers across the 2 years of data, we imputed the answer reflecting their highest level of participation. Hospitals that did not respond to the HIE survey in 2017 and 2018 or who did not respond to the participation in HIE questions were excluded from the analysis.

We classified information sharing into 4 distinct categories: same-hospital readmissions and 3 categories of information exchange between different hospitals with fragmented readmissions. The first type of information sharing was “same-hospital readmission.” In this scenario, all the information from the initial admission should be readily available in the patient’s medical record during their readmission, so there is no expectation that the hospital’s HIE status would have an impact on the quality of care they received. Because these patients did not experience care fragmentation, this group served as the reference group for subsequent analyses. Second, patients could have a fragmented readmission to different hospitals in which both hospitals participate in the same HIE based on their answers to the AHA IT survey (ie, “fragmented/same HIE”). In this scenario, the information from the index admission is available to the readmission hospital via the HIE. The third type of information sharing was a fragmented readmission to different hospitals in which each hospital participated in an HIE, but the HIEs were different between the admission and readmission hospitals (ie, “fragmented/different HIE”). This category captures hospitals that participate in an HIE because they may be different than hospitals that do not participate in HIE, but in this scenario, there is no clear method of electronic information exchange between the admission and readmission hospitals, so information from the index admission is not available to clinicians at the readmission hospital. The final category was “no information shared”: fragmented readmissions to different hospitals in which one or both hospitals indicated on the survey that they did not participate in an HIE (ie, “fragmented/no HIE”). Because a beneficiary could have multiple admission-readmission pairs in this analysis, they could have a pair in more than one category of information sharing. In both the fragmented/different HIE and the fragmented/no HIE categories, there is less expectation that participation in different HIEs by both hospitals or participation in an HIE by only one hospital would have an impact on the quality of care.

Outcomes: In-Hospital and 30-Day Postdischarge Mortality

The outcomes of interest for this study were all-cause in-hospital mortality and all-cause mortality in the 30 days following discharge from the readmission (among beneficiaries who survived their readmission). We used the death date of each beneficiary, where applicable, to determine vital status and when the beneficiary died.

Covariates

We included several beneficiary demographic and clinical characteristics, as well as hospital characteristics, in our models. Demographic characteristics included the beneficiary’s age, sex, and race (White, Black, or other). Clinical characteristics included a frailty score, the number of chronic conditions, the reason for readmission to the hospital, and if the beneficiary was admitted to the intensive care unit (ICU) during the readmission. The frailty score ranges from 0 to 1, with a higher score indicating greater frailty; it was calculated using a deficit-accumulation model using 93 claims-based variables [29,30]. The number of chronic conditions was measured by counting the number of chronic conditions with which the beneficiary was ever diagnosed in the Chronic Conditions Supplement, which reports 27 chronic conditions [28]. Reason for readmission was divided into 9 categories, based on the 8 categories of interest identified for index admissions and 1 “other reason” category.

Hospital characteristics included hospital size (<500 or ≥500 beds), ownership (government, religious, nonprofit, or for-profit), hospital type (general medical/surgical, or other), urban/rural status of the hospital (metropolitan, micropolitan, or rural), and if the hospital was a teaching hospital or not. Urban/rural status was identified via the Rural Urban Commuting Area codes of the hospital [31]. Hospitals were classified as teaching hospitals if they reported that they had programs accredited by the American Council of Graduate Medical Education, the American Osteopathic Association, or the Council of Teaching Hospitals, or if they were affiliated with a medical school. Hospitals were categorized as either general medical/surgical or “other,” which included specialty hospitals [21].

Analytic Approach

Univariate statistics were used to describe and compare clinical and demographic characteristics between admission-readmission pairs across categories of information sharing. Hospital characteristics by HIE status across all hospitals that responded to the AHA Annual Survey and AHA IT survey were also assessed.

To evaluate whether electronic information sharing via HIE between admission and readmission hospitals was associated with in-hospital or postdischarge mortality, we performed unadjusted and adjusted logistic regressions. Regression analyses were adjusted separately for patient demographics and clinical characteristics (age, sex, race, frailty score, number of chronic conditions, reason for readmission, and ICU use during readmission) and for readmission hospital characteristics (number of beds, ownership, hospital type, urban/rural location, and teaching status). Regressions included hospital fixed effects to adjust for unmeasured differences between hospitals. Robust standard errors clustered at the hospital level were used.

We also completed several sensitivity analyses. First, to test the influence of rural hospitals, which may have different market structures than micropolitan or urban hospitals, we removed readmissions to rural hospitals. Second, we limited the analysis to beneficiaries who did not have an ICU stay during their index hospital admission to select for patients at lower risk for death. Third, to determine if HIE use might have a stronger association with mortality in patients at higher risk for mortality, we calculated the probability of dying within 90 days following hospital discharge and analyzed only beneficiaries with a 90-day
mortality probability of >0.25. We also created propensity-score matched cohorts on the odds of 30-day postdischarge mortality using optimal matching without replacement; this was done to balance the odds of dying across information-sharing categories. Finally, to test if patients who are frequently admitted to the same hospital had a disproportionate influence on the results of same hospital admission-readmission pairs, we limited the same-hospital category to only the first pair for each beneficiary. Analyses were completed in SAS (version 9.4; SAS Institute) and Stata (version 17; Stata Corp).

**Ethical Considerations**

This study was approved by the Institutional Review Board of Emory University School of Medicine (#00000108) and funded by the National Institute on Aging of the National Institutes of Health (K23AG065505).

**Results**

**Participant Characteristics**

The initial sample had 8,316,909 claims. We removed noninpatient claims, interhospital transfers, and observations missing beneficiary identification numbers. We then created admission-readmission pairs; after limiting the pairs to readmissions within 30 days, limiting the pairs to index admissions for the initial diagnoses of interest, and removing pairs in which the beneficiary was listed as deceased after their index admission, we had 428,988 pairs (including 279,729 unique patients). Next, we removed observations with missing HIE data due to nonresponse to the AHA IT survey or nonresponse to the HIE questions on the AHA IT survey (n=71,367, 16.6% of pairs were removed). Of the remaining 357,621 pairs, 8.1% were for beneficiaries with AD (n=28,946 pairs comprising 28,741 unique patients), representing the final sample. Full details of the sample development can be found in Figure 1.

Beneficiaries with same-hospital readmissions were older (aged 81.1, SD 8.6 years) than beneficiaries with readmissions to a different hospital (age range 79.8-80.3 years, \( P < .001 \); Table 1). There were no differences in frailty score or chronic condition count across the categories of information sharing. While 49.9% of hospitals that responded to the AHA and AHA IT surveys reported participating in an HIE (Multimedia Appendix 3), only 2.1% (601/28,946) of admission-readmission pairs were to hospitals that shared an HIE. Overall, 5.9% (1704/28,946) of beneficiaries died during their readmission, and 19.6% (5667/28,946) died in the 30 days following hospital readmission (Table 1).
Table 1. Demographic and clinical information of admission-readmission pairs among Medicare beneficiaries with Alzheimer disease in 2018.

<table>
<thead>
<tr>
<th>Age (years), mean (SD)</th>
<th>Total (n=28,946)</th>
<th>Same-hospital readmission (n=24,952)</th>
<th>Fragmented readmission</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Same HIE(^a) (n=601)</td>
<td>Different HIEs (n=2105)</td>
<td>No HIE (n=1288)</td>
</tr>
<tr>
<td>80.9 (8.6)</td>
<td>81.1 (8.6)</td>
<td>80.3 (8.7)</td>
<td>80.1 (8.6)</td>
<td>79.8 (8.4)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sex, n (%)</th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>16,163 (55.8)</td>
<td>14,004 (56.1)</td>
<td>.10</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>12,783 (44.2)</td>
<td>10,948 (43.9)</td>
<td></td>
</tr>
<tr>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Race, n (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White</td>
<td>24,097 (83.2)</td>
<td>20,976 (84.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>Black</td>
<td>3341 (11.5)</td>
<td>2692 (10.8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1508 (5.2)</td>
<td>1284 (5.1)</td>
<td></td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Urban/rural status, n (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan</td>
<td>25,110 (87.1)</td>
<td>21,641 (87)</td>
<td>526 (87.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Micropolitan</td>
<td>2748 (9.5)</td>
<td>2424 (9.7)</td>
<td>43 (7.2)</td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>985 (3.4)</td>
<td>797 (3.2)</td>
<td>30 (5)</td>
<td></td>
</tr>
<tr>
<td>Frailty score, mean (SD)</td>
<td>0.20 (0.05)</td>
<td>0.20 (0.05)</td>
<td>0.20 (0.05)</td>
<td>.45</td>
</tr>
<tr>
<td>Chronic condition count, mean (SD)</td>
<td>20.7 (6.2)</td>
<td>20.7 (6.2)</td>
<td>20.4 (6.0)</td>
<td>20.5 (6.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reason for admission, n (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MI(^b)</td>
<td>2451 (8.5)</td>
<td>2047 (8.2)</td>
<td>57 (9.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CHF(^c)</td>
<td>12,103 (41.8)</td>
<td>10,496 (42.1)</td>
<td>266 (44.3)</td>
<td></td>
</tr>
<tr>
<td>COPD(^d)</td>
<td>3916 (13.5)</td>
<td>3405 (13.6)</td>
<td>76 (12.6)</td>
<td></td>
</tr>
<tr>
<td>Pneumonia</td>
<td>4716 (16.3)</td>
<td>4097 (16.4)</td>
<td>91 (15.1)</td>
<td></td>
</tr>
<tr>
<td>Dehydration</td>
<td>1311 (4.5)</td>
<td>1101 (4.4)</td>
<td>33 (5.5)</td>
<td></td>
</tr>
<tr>
<td>Syncope</td>
<td>459 (1.6)</td>
<td>364 (1.5)</td>
<td>13 (2.2)</td>
<td></td>
</tr>
<tr>
<td>UTI(^f)</td>
<td>3954 (13.7)</td>
<td>3411 (13.7)</td>
<td>65 (10.8)</td>
<td></td>
</tr>
<tr>
<td>Behavioral issues</td>
<td>36 (0.1)</td>
<td>31 (0.1)</td>
<td>0 (0)</td>
<td>1 (0.01)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reason for readmission, n (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MI</td>
<td>651 (2.2)</td>
<td>516 (2.1)</td>
<td>29 (4.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CHF</td>
<td>6362 (22)</td>
<td>5584 (22.4)</td>
<td>125 (20.8)</td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td>1743 (6)</td>
<td>1551 (6.2)</td>
<td>27 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1376 (4.7)</td>
<td>1238 (5)</td>
<td>18 (3)</td>
<td></td>
</tr>
<tr>
<td>Dehydration</td>
<td>434 (1.5)</td>
<td>379 (1.5)</td>
<td>6 (1)</td>
<td></td>
</tr>
<tr>
<td>Syncope</td>
<td>132 (0.5)</td>
<td>111 (0.4)</td>
<td>4 (0.7)</td>
<td></td>
</tr>
<tr>
<td>UTI</td>
<td>936 (3.2)</td>
<td>838 (3.4)</td>
<td>8 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Behavioral issues</td>
<td>7 (0.02)</td>
<td>6 (0.02)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>17305 (59.8)</td>
<td>14,729 (59)</td>
<td>384 (63.9)</td>
<td></td>
</tr>
</tbody>
</table>

| ICU stay admission          | 8651 (29.9)      | 7483 (30)                        | 153 (25.5)            |         |
| ICU stay readmission        | 9727 (33.6)      | 8269 (33.1)                      | 202 (33.6)            |         |

<table>
<thead>
<tr>
<th>Readmission hospital number of beds, n (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;500 beds</td>
<td>21,789 (75.5)</td>
<td>18,909 (76.1)</td>
<td>401 (66.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>≥500 beds</td>
<td>7051 (24.5)</td>
<td>5953 (23.9)</td>
<td>199 (33.2)</td>
<td></td>
</tr>
</tbody>
</table>
## In-Hospital Mortality

Compared to same-hospital readmissions, older adults with AD admitted to a different hospital with a shared HIE had 39% lower odds of dying during their readmission (odds ratio [OR] 0.61, 95% CI 0.39-0.95; Table 2), accounting for readmission hospital fixed effects (not shown in table), demographics, clinical characteristics, and hospital characteristics. Beneficiaries with fragmented/different HIE readmissions had no statistically significant difference in the odds of dying during the readmission compared to same-hospital readmissions (adjusted odds ratio [AOR] 1.02, 95% CI 0.82-1.28). Beneficiaries with fragmented/no HIE had 33% increased odds of in-hospital mortality compared to same-hospital readmissions when adjusting for hospital characteristics only (AOR 1.33, 95% CI 1.01-1.75); however, the difference did not remain statistically significant when patient demographics and clinical characteristics were included (AOR 1.25, 95% CI 0.93-1.68).

### Table 2. Unadjusted and logistic regressions for in-hospital mortality across categories of information sharing among Medicare beneficiaries with Alzheimer disease in 2018. All analyses are compared to same-hospital readmission pairs. Each model includes readmission hospital fixed effects; robust standard errors are clustered at the level of the hospital. Model 1: demographics (age, sex, race) and clinical characteristics (frailty score, chronic condition count, reason for readmission, intensive care unit stay during readmission); model 2: hospital characteristics (urban/rural, size, ownership, type, teaching status, each for readmission hospital); model 3: full model.

<table>
<thead>
<tr>
<th>Category</th>
<th>Model 1 (n=18,072), adjusted OR (95% CI)</th>
<th>Model 2 (n=18,157), adjusted OR (95% CI)</th>
<th>Model 3 (n=18,036), adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same HIE</td>
<td>0.61 (0.39-0.95)</td>
<td>0.72 (0.47-1.12)</td>
<td>0.61 (0.39-0.95)</td>
</tr>
<tr>
<td>Different HIEs</td>
<td>1.09 (0.88-1.34)</td>
<td>1.33 (1.01-1.75)</td>
<td>1.25 (0.93-1.68)</td>
</tr>
<tr>
<td>No HIE participation</td>
<td>1.24 (0.92-1.66)</td>
<td>1.33 (1.01-1.75)</td>
<td>1.25 (0.93-1.68)</td>
</tr>
</tbody>
</table>

### Thirty-Day Postdischarge Mortality

In unadjusted and adjusted regression models examining the odds of dying in the 30 days following hospital readmission compared to same-hospital readmission, no category of information sharing in fragmented readmissions was associated with postdischarge mortality (Table 3; hospital fixed effects not shown). However, admission-readmission pairs to different
hospitals that participated in different HIEs trended toward significance when the model included hospital characteristics only (AOR 1.13, 95% CI 0.99-1.29; P=.06), but these results were not statistically significant.

Table 3. Unadjusted and logistic regressions for postdischarge mortality across categories of information sharing among Medicare beneficiaries with Alzheimer disease in 2018. All analyses are compared to same-hospital readmission pairs. Each model includes readmission hospital fixed effects; robust standard errors are clustered at the level of the hospital. Model 1: demographics (age, sex, race) and clinical characteristics (frailty score, chronic condition count, reason for readmission, intensive care unit stay during readmission); model 2: hospital characteristics (urban/rural, size, ownership, type, teaching status, each for readmission hospital); model 3: full model.

<table>
<thead>
<tr>
<th>HIE Type</th>
<th>Unadjusted OR (^{a,b}) (95% CI)</th>
<th>Model 1 (n=25,668), adjusted OR (95% CI)</th>
<th>Model 2 (n=25,772), adjusted OR (95% CI)</th>
<th>Model 3 (n=25,569), adjusted OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fragmented/same HIE(^c)</td>
<td>1.00 (0.78-1.28)</td>
<td>0.95 (0.73-1.22)</td>
<td>1.00 (0.78-1.28)</td>
<td>0.95 (0.74-1.23)</td>
</tr>
<tr>
<td>Fragmented/different HIEs</td>
<td>1.13 (0.99-1.29)</td>
<td>1.11 (0.97-1.27)</td>
<td>1.13 (0.99-1.29)</td>
<td>1.11 (0.97-1.27)</td>
</tr>
<tr>
<td>Fragmented/no HIE participation</td>
<td>1.12 (0.94-1.33)</td>
<td>1.09 (0.91-1.31)</td>
<td>1.12 (0.94-1.33)</td>
<td>1.09 (0.91-1.31)</td>
</tr>
</tbody>
</table>

\(^a\)OR: odds ratio.
\(^b\)n=28,874.
\(^c\)HIE: health information exchange.

**Sensitivity Analyses**

When rural hospitals were removed to examine the effect of differences between metropolitan or micropolitan and rural market forces, the results of the analyses for both in-hospital and postdischarge mortality were similar to the primary analysis (Multimedia Appendix 4, Tables S1 and S2). When we removed beneficiaries with a probability of 90-day mortality <0.25, the association between fragmented/same HIE and lower odds of in-hospital mortality did not reach statistical significance, likely due to being underpowered (AOR 0.59, 95% CI 0.33-1.07; Multimedia Appendix 4, Table S5); all other associations were similar to the primary analysis (Multimedia Appendix 4, Tables S3-S10). Notably, when we created groups matched on the probably of mortality across information-sharing categories, the primary finding of lower in-hospital mortality remained (AOR 0.61, 95% CI 0.39-0.95; Multimedia Appendix 4, Table S7).

**Discussion**

**Principal Findings**

In this study, we sought to measure the association between HIE availability at the hospital level and in-hospital and postdischarge mortality following readmissions to a different hospital among older adults with AD. Compared to readmissions to the same hospital, a shared HIE during fragmented readmissions was associated with 39% lower in-hospital mortality. This benefit did not extend past the hospitalization, as there were no differences observed across the categories of HIE sharing for postdischarge mortality.

**Comparison to Prior Work**

There have been a limited number of previous studies examining the relationship between HIE presence and inpatient mortality [32]: one focused on patients admitted with acute myocardial infarction found no benefit of HIEs [15], while another focusing on HIE use in interhospital transfers found a 25% lower odds of inpatient mortality [33]. Our study advances the literature in two key ways: first, by focusing on a patient population that may stand to gain outsized benefit from information exchange, and second, by using a more focused definition of information exchange—namely, whether or not the admitting and readmitting hospital participated in the same HIE—to reduce misclassification bias.

**Strengths and Limitations**

This study has several limitations. First, one important unmeasured potential confounder of the relationship between electronic information exchange and mortality among older adults with AD is the presence of a caregiver. Because caregiver status and their presence during a hospital admission is not available in Medicare claims data, we were not able to assess whether caregivers were more or less likely to go to the hospital with their loved ones during fragmented or nonfragmented readmissions; and if they were present, it is unclear whether they might have served as a type of “human information exchange” for the care team. Qualitative data regarding patient and caregiver perceptions of fragmented versus nonfragmented readmissions, as well as patient and caregiver views on their role in transmitting information across fragmented settings of care, would help address this question.

Second, as with any study where HIE availability is used as a proxy for HIE use by providers, we do not know whether providers accessed the outside information, the quality or content of data shared via electronic information exchange, and, if providers accessed the data, when and how they incorporated the data into their clinical decision-making; this limitation is shared with many other studies of HIEs [13,15,33,34]. Previous work has suggested that providers do not often access HIEs [35,36], mainly because they do not perceive that HIEs contain clinically useful information [37]. Even if HIEs were accessed, we do not know how providers used the information obtained from the HIEs. Perhaps they accessed advance directives and adjusted their care plans to reflect patients’ wishes, or perhaps they reviewed old results and images that could lead to anchoring bias and potential missed diagnoses for the patient. Because the Office of the National Coordinator for Health Information Technology has made HIE availability a priority [38], HIE prevalence and use in clinical decision-making will likely grow over the coming years, and work should continue...
to understand how and when information contained within HIEs impacts patient outcomes. Further investigation into actual provider use of HIE at the point of care will allow researchers to go beyond HIE presence as a proxy for HIE use and will facilitate measurement of the association between how HIEs are used and patient outcomes.

Conclusions
Overall, this study contributes to our understanding of the impact and limitations of HIEs as tools to mitigate the information discontinuity present in fragmented readmissions. It also furthers our understanding of the impact of care fragmentation on older adults with AD and how we can harness existing systems within the health IT infrastructure to lessen the effects of interhospital fragmentation of care in this population.

Acknowledgments
The authors would like to thank Allan Levey, MD, PhD, for his input on the manuscript. Research reported in this publication was supported by the National Institute on Aging of the National Institutes of Health (K23AG065505), by the Program for Retaining, Supporting, and Elevating Early-Career Researchers at Emory (PeRSEVERE) from the Emory School of Medicine, by a gift from the Doris Duke Charitable Foundation, and through the Georgia Clinical and Translational Science Alliance National Institutes of Health (award UL1-TR002378). This material is the result of work supported with resources and the use of facilities at the Atlanta Veterans Affairs Health Care System. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or the Department of Veterans Affairs. The sponsors had no role in the design, methods, subject recruitment, data collection, analysis, or preparation of the manuscript. ST and MKA have received funding from Merck for research unrelated to this work.

Data Availability
The data sets analyzed during the current study are not publicly available due to the data use agreement required by the Research Data Access Center/Centers for Medicare and Medicaid Services for use of identifiable Medicare data. Data are available from the corresponding author upon reasonable request and with permission of the Research Data Access Center.

Authors' Contributions
ST, CPV, SDC, KWH, KJR, MMP, CKC, and MKA contributed to conception, results interpretation, and editing the manuscript. ST and MKA contributed to data acquisition and data analysis. ST drafted the manuscript.

Conflicts of Interest
ST and MKA have received funding from Merck for research unrelated to this work.

Multimedia Appendix 1
ICD-10 and DRG Codes Used for Index Admissions.
[DOCX File, 19 KB - aging_v61e41936_app1.docx]

Multimedia Appendix 2
Illustration of Admission-Readmission Pairs.
[DOCX File, 36 KB - aging_v61e41936_app2.docx]

Multimedia Appendix 3
[DOCX File, 17 KB - aging_v61e41936_app3.docx]

Multimedia Appendix 4
Results of Sensitivity Analyses.
[DOCX File, 25 KB - aging_v61e41936_app4.docx]

References


12. Kuperman GJ. Health-information exchange: why are we doing it, and what are we doing? J Am Med Inform Assoc 2011;18(5):678-682 [FREE Full text] [doi: 10.1136/amiajnl-2010-000021] [Medline: 21676940]


24. Hospital Readmissions Reduction Program: Fiscal Year (FY) 2019 Fact Sheet. Centers for Medicare and Medicaid Services. URL: https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/Readmissions-Reduction-Program [accessed 2020-08-01]


Abbreviations

AD: Alzheimer disease
AHA: American Hospital Association
AMI: myocardial infarction
CHF: congestive heart failure
CMS: Centers for Medicare and Medicaid Services
COPD: chronic obstructive pulmonary disease
HIE: health information exchange
HRRP: Hospital Readmissions Reduction Program
ICU: intensive care unit
IT: information technology
MedPar: Medicare Provider Analysis and Review
UTI: urinary tract infection
Patient Perceptions of e-Visits: Qualitative Study of Older Adults to Inform Health System Implementation

Timothy J Judson1*, MD, MPH; Meera Subash2*, MD; James D Harrison1, PhD; Jan Yeager3, MDes; Aimée M Williams3, MPH; Carrie K Grouse4, MD; Maria Byron1, MD

1Department of Medicine, University of California San Francisco, San Francisco, CA, United States
2Houston School of Biomedical Informatics, UTHealth, Houston, TX, United States
3Clinical Innovation Center, University of California San Francisco, San Francisco, CA, United States
4Department of Neurology, University of California San Francisco, San Francisco, CA, United States
*these authors contributed equally

Corresponding Author:
Timothy J Judson, MD, MPH
Department of Medicine
University of California San Francisco
Box 0131
521 Parnassus Avenue
San Francisco, CA, 94143
United States
Phone: 1 415 514 8755
Email: Timothy.judson@ucsf.edu

Abstract

Background: Electronic visits (e-visits) are billable, asynchronous patient-initiated messages that require at least five minutes of medical decision-making by a provider. Unequal use of patient portal tools like e-visits by certain patient populations may worsen health disparities. To date, no study has attempted to qualitatively assess perceptions of e-visits in older adults.

Objective: In this qualitative study, we aimed to understand patient perceptions of e-visits, including their perceived utility, barriers to use, and care implications, with a focus on vulnerable patient groups.

Methods: We conducted a qualitative study using in-depth structured individual interviews with patients from diverse backgrounds to assess their knowledge and perceptions surrounding e-visits as compared with unbilled portal messages and other visit types. We used content analysis to analyze interview data.

Results: We conducted 20 interviews, all in adults older than 65 years. We identified 4 overarching coding categories or themes. First, participants were generally accepting of the concept of e-visits and willing to try them. Second, nearly two-thirds of the participants voiced a preference for synchronous communication. Third, participants had specific concerns about the name “e-visit” and when to choose this type of visit in the patient portal. Fourth, some participants indicated discomfort using or accessing technology for e-visits. Financial barriers to the use of e-visits was not a common theme.

Conclusions: Our findings suggest that older adults are generally accepting of the concept of e-visits, but uptake may be limited due to their preference for synchronous communication. We identified several opportunities to improve e-visit implementation.

(KEYWORDS

e-visit; patient portal message; digital health tool; patient portal; perception; attitude; qualitative; e-consult; remote care; remote visit; remote consult; vulnerable; messaging; telehealth; telemedicine; eHealth

Introduction

Electronic visits (e-visits) allow patients to get web-based medical advice without the need for a face-to-face visit. They are billable, asynchronous patient-initiated messages that are sent through a patient portal and require at least five minutes of medical decision-making by a provider [1]. There are several benefits of e-visits to patients. They provide a flexible option for obtaining medical care that does not require travel or time off from work, which may save patients time and money [2,3].
Studies have demonstrated improvements in access to care for patients in rural areas [4-6] and equivalent patient outcomes at a lower cost [7]. For physicians, e-visits are attractive because unlike other patient portal messages, they provide a mechanism for reimbursement [8], and therefore, may lead to direct compensation or credit toward productivity targets.

E-visits have been used for the management of chronic conditions and for consultation on nonurgent acute health concerns [9,10]. The use and flexibility for reimbursement of e-visits has increased in recent years [11,12]. In 2020, the Centers for Medicare and Medicaid services began to cover e-visits in all types of locations, including the patient’s home, and in all areas of the country, rather than just rural areas [12]. Particularly during the COVID-19 pandemic, e-visits have become an increasingly important means of providing virtual care [12].

E-visits are only available to patients who use patient portals, creating the potential for health disparities. Specifically, older adults and those from minority backgrounds are less likely to enroll in patient portals [13-15]. Barriers to using digital tools like patient portals include limited internet access, low computer skills, and strong habits associated with face-to-face or phone scheduling [16]. As health systems shift toward providing more virtual care [17,18], it is crucial that we understand the interest and ability of vulnerable patient groups to use these digital tools so as to prevent worsening health disparities. Furthermore, when health systems begin to offer e-visits, they may see low uptake and dissatisfaction if key patient groups are uncomfortable with their use. Although several studies have evaluated the demographic characteristics of patients who use e-visits [9,10,19] and providers who offer them [4,7,20], little is known about how patients at risk of digital health disparities perceive this visit type, particularly compared to traditional, nonbillable patient portal messages. Therefore, in this qualitative study, we aimed to understand patient perceptions of e-visits, including their perceived utility, barriers to use, and care implications, with a focus on vulnerable patient groups.

**Methods**

**Study Setting**

We conducted this study at University of California, San Francisco (UCSF) Health, a large tertiary academic medical center that originally introduced e-visits in 2020 and was considering a change to how e-visits were offered to patients. UCSF uses a commercially available electronic health record from Epic Systems. Over 90% of patients empaneled to UCSF primary care were enrolled in the patient portal during the time of the study.

**Study Design and Oversight**

We conducted a qualitative study using in-depth structured individual interviews with patients from diverse backgrounds to assess their knowledge and perceptions surrounding e-visits as compared with portal messages and other visit types. We specifically explored their perceptions of the acceptability and usability of e-visits.

**Ethical Considerations**

This study was reviewed and deemed exempt by the University of California at San Francisco Institutional Review Board.

**Study Recruitment**

Potential participants were identified from among patients who received primary care at UCSF Health. To include patients with varying degrees of comfort using web-based patient portals for their care, we recruited half of the participants from among patients who had used a patient portal–based triage tool [21] and half of the participants from among patients who had used an identical telephone-based triage tool in the past 6 months. We hypothesized that patients who had opted to use the patient portal tool were more likely to be comfortable using other patient portal tools and that patients who had opted to use the more time-consuming telephone tool might be less comfortable or less preferential toward using other patient portal tools, such as e-visits.

To ensure representation from a diverse sample of patients, we then further identified those who met the following criteria: Latinx ethnicity, African American race, having MediCal (Medicaid) insurance, living outside of the 9 San Francisco Bay Area counties, and non–English speaking. We randomly selected at least two participants from each of these groups before recruiting a random selection of patients, regardless of their demographic characteristics, until we reached saturation of responses. Race and ethnicity were treated as social rather than biologic constructs and were included as a proxy for unmeasured factors experienced by socially marginalized populations that may predict their experience using e-visits. We used MediCal insurance as a proxy for low socioeconomic status. The researchers did not have previous treatment relationships with the participants.

On the initial phone call, the research coordinator described the study, and for those interested in participating, obtained informed consent and scheduled an interview. Participants were given a US $60 gift card for their participation, which was sent to them prior to completing the interview.

**Participant Interviews**

A trained service designer (JY) with extensive experience in human-centered design and qualitative research conducted an approximately 60-minute interview with each participant. Interviews were conducted by Zoom videoconferencing, if possible. If the participant was unable to use video, they were conducted by telephone. If patients preferred, they could invite a caretaker, such as an adult child, to join the interview. The service designer used a structured interview guide (Multimedia Appendix 1), which included the following domains: current methods of communicating with providers, perceptions of e-visits and patient portal messages, financial aspects of e-visits, naming conventions for e-visits, self-assessment of health technology literacy, and current health status. This interview guide, consisting of mostly open-ended questions, was developed after conducting a review of literature and lay press to identify potential risks and benefits of e-visits, particularly compared to other visit types. Certain questions were adapted from validated questionnaires [22,23]. Participants could elect...
not to answer any question. Patient interviews were digitally recorded and transcribed using the transcription service Tigerfish [24].

Transcription Review and Analysis

We used a combination of qualitative and quantitative content analysis to analyze interview data [25,26]. Transcripts were reviewed independently by 2 clinician investigators (TJJ and MS) under the guidance of a trained qualitative researcher (JDH). We organized data analysis around the study questions: acceptability, usability, as well as financial and care implications. We first used qualitative content analysis to systematically examine the transcripts to obtain a condensed understanding and description of content [25]. We used a data-driven (inductive) approach to analysis whereby open coding was performed to identify salient and elevated topics of importance within the data set. To ensure trustworthiness, throughout analysis, reviewers (TJJ, MS, and JDH) met to refine and define coding categories, and coding disparities were discussed and resolved by negotiated consensus [27]. Coding categories were then grouped into higher-order categories or themes.

Quantitative content analysis was then performed to count coding categories. This was conducted for the purpose of providing a more detailed assessment of how frequently certain themes or codes were mentioned. For each code, there was at least one corresponding question in the interview guide pertaining to that topic. For the purposes of determining the proportion of responses related to a particular code or coding category, we excluded participants from the denominator if they did not answer the pertinent question(s). We then did a secondary analysis comparing themes between patients who had used the patient portal tool in the past 6 months, compared to those who had not. We aimed to enroll until we reached saturation of responses, which we defined as having done at least 9-17 interviews [28] and observing the repetition of themes without significant new insights.

Sharing Findings With the Health System

After analyzing qualitative themes and identifying key patient responses, we shared findings with health systems leadership to inform informatics and operational changes related to the broader implementation of e-visits at the institution.

Results

From April 2021 to June 2021, we conducted qualitative interviews with a total of 20 adults (Table 1). The median age was 74 (IQR 68.5-77.8) years. Of 20 participants, 13 (65%) identified as male, and 7 (35%) identified as female; 10/20 (50%) participants identified as White or Caucasian, 5/20 (25%) as Asian, 2/20 (10%) as Black or African American, 1/20 (5%) as American Indian or Alaska Native, and 2/20 (10%) as a race not listed. Of the 20 participants, 3 (15%) identified as Latinx, and 2 (10%) patients had limited English proficiency. Most patients (14/20, 70%) had Medicare insurance. All patients had an active patient portal account. One of the interviewed participants reported having used an e-visit before.
Table 1. Interview participants baseline characteristics.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values (N=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), median (IQR)</td>
<td>74 (68.5-77.8)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>7 (35)</td>
</tr>
<tr>
<td>Male</td>
<td>13 (65)</td>
</tr>
<tr>
<td>Race, n (%)</td>
<td></td>
</tr>
<tr>
<td>American Indian or Alaska Native</td>
<td>1 (5)</td>
</tr>
<tr>
<td>Asian</td>
<td>5 (25)</td>
</tr>
<tr>
<td>Black or African American</td>
<td>2 (10)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (10)</td>
</tr>
<tr>
<td>White or Caucasian</td>
<td>10 (50)</td>
</tr>
<tr>
<td>Ethnicity, n (%)</td>
<td></td>
</tr>
<tr>
<td>Hispanic or Latinx</td>
<td>3 (15)</td>
</tr>
<tr>
<td>Not Hispanic or Latinx</td>
<td>17 (85)</td>
</tr>
<tr>
<td>Limited English proficiency</td>
<td>2 (10)</td>
</tr>
<tr>
<td>County of residence, n (%)</td>
<td></td>
</tr>
<tr>
<td>San Francisco</td>
<td>14 (70)</td>
</tr>
<tr>
<td>Other</td>
<td>6 (30)</td>
</tr>
<tr>
<td>Insurance, n (%)</td>
<td></td>
</tr>
<tr>
<td>Medicare</td>
<td>14 (70)</td>
</tr>
<tr>
<td>Medicare advantage</td>
<td>2 (10)</td>
</tr>
<tr>
<td>Medicaid</td>
<td>3 (15)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (5)</td>
</tr>
</tbody>
</table>

We identified 4 overarching coding categories or themes, comprising 7 codes (Table 2).

These themes stemmed from a combination of both prompted (in response to an interviewer question) and unprompted (ie, spontaneous) comments from participants. First, participants generally were accepting of the concept of e-visits and were willing to try them. For example, after hearing about the effort to make this visit type available to patients, one participant stated “I wholeheartedly endorse that. I think it’s not just a good idea, it’s essential.” Participants voiced that e-visits may be most helpful to prevent office visits. For example, one participant stated, “the actual cost [of an in-person visit] is a lot more because of transportation…and lost opportunity to do something else.” Participants also generally agreed with the idea that providers should be fairly compensated for time spent on medical decision-making, whether in a synchronous visit (eg, video visit) or asynchronous visit (eg, e-visit).

Second, nearly two-thirds (10/16) of the participants voiced a preference for synchronous communication. In many cases, in-person visits were preferred. These preferences stemmed from improved perceptions of communication and comprehension by both patients and physicians.

Third, some participants had specific concerns about e-visits. Many found the name confusing and thought they should instead have a more descriptive name, such as “online medical advice.” Participants also voiced concern about choosing the right visit type in the patient portal and did not think it should be left up to the patient to determine whether they should submit a billable e-visit or nonbillable message. Participants also voiced discomfort expressing medical questions in writing. One participant stated, “You’re relying upon your narrative. You have to express in [the patient portal] within a certain amount of words exactly what the issue is. And believe me, that sometimes can’t be captured.” Only 2 of the 7 participants who expressed this concern had limited English proficiency.

Fourth, 6/18 (33%) participants indicated discomfort using or accessing technology for e-visits. For example, the daughter of one participant stated “[My parents] don’t have the computer skills. They are from the telephone era. They prefer talking to a human being and it makes sense to them versus typing.”

Financial barriers were not a common theme, with only 3/18 (17%) patients expressing concern over increased out of pocket costs resulting from patient portal messages being converted to billable e-visits. Only 3/18 (17%) participants thought that precise out-of-pocket patient costs for e-visits need to be stated up front before a patient sends a message. However, participants did expect that the out-of-pocket costs for e-visits should be less than or equal to the costs for a synchronous visit. The most
commonly quoted amount that participants reported they would pay out of pocket for an e-visit was US $20.

There were minimal differences in themes between participants who did or did not use the patient portal tool in the past 6 months. For example, 6/9 (67%) participants recruited from the patient portal group liked the idea of e-visits versus 5/10 (50%) participants recruited from the telephone hotline group. A total of 4 participants recruited from each group reported discomfort using technology.

Table 2. Summary of coding categories and codes describing patient perspectives of e-visits.

<table>
<thead>
<tr>
<th>Higher-order coding category or theme</th>
<th>Code</th>
<th>Proportion(^a), n/N</th>
<th>Sample quotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance of the concept of e-visits</td>
<td>Favors the idea of e-visits</td>
<td>11/19</td>
<td>• “I wholeheartedly endorse that. I think it’s not just a good idea, it’s essential”</td>
</tr>
<tr>
<td>Willing to try e-visits</td>
<td>14/18</td>
<td>• “All of sudden [if I] have sores in my mouth or something like that, I'm sure that could be handled through an e-visit.”</td>
<td></td>
</tr>
<tr>
<td>Thinks e-visits may help prevent office visits</td>
<td>11/16</td>
<td>• “The actual cost [of an in-person visit] is a lot more because of transportation…and lost opportunity to do something else”</td>
<td></td>
</tr>
<tr>
<td>Thinks providers should be fairly compensated for their time</td>
<td>11/18</td>
<td>• “I am still using his time, so he definitely should get compensated for that because they are giving me medical advice”</td>
<td></td>
</tr>
<tr>
<td>Preference for synchronous communication(^b)</td>
<td>Preference for synchronous communication(^b)</td>
<td>10/16</td>
<td>• “[The patient portal] is not very effective because there’s a lot of miscommunication and misunderstanding.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• “I’m constantly having to ask for repetition. This is good because it helps me understand if the doctor is understanding me, as well as me understanding the doctor. In a text message you don’t get that.”</td>
</tr>
<tr>
<td>Concerns about e-visits</td>
<td>Naming convention is confusing</td>
<td>10/16</td>
<td>• “I don’t know what it means…I think you would have to say something like an online visit, or online medical advice”</td>
</tr>
<tr>
<td></td>
<td>Difficulty choosing right visit type within the patient portal</td>
<td>8/14</td>
<td>• “the doctor [should] make the call.”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• “if there were some guidelines, that could help the patient”</td>
</tr>
<tr>
<td></td>
<td>Discomfort expressing medical questions in writing</td>
<td>7/18</td>
<td>• “You’re relying upon your narrative. You have to express in [the patient portal] within a certain amount of words exactly what the issue is. And believe me, that sometimes can’t be captured.”</td>
</tr>
<tr>
<td>Discomfort using technology(^b)</td>
<td>Discomfort using technology(^b)</td>
<td>6/18</td>
<td>• “[My parents] don’t have the computer skills. They are from the telephone era. They prefer talking to a human being and it makes sense to them versus typing…”</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• “I never could remember my password. Well, ok, that’s because I’m old.”</td>
</tr>
</tbody>
</table>

\(^a\)We excluded participants from the denominator if they did not answer the pertinent question(s).

\(^b\)Singular topics that were common within the data set are included as both a code and a theme.

**Discussion**

**Principal Findings**

The majority of participants in this study were accepting of the idea of e-visits—billable, asynchronous patient-initiated messages—and willing to try one, despite preferring synchronous visits. Most participants agreed that providers should be fairly compensated for medical decision-making. Although they opined that out-of-pocket costs should be similar to or less than the cost for synchronous visits, they did not voice major concerns over additional out-of-pocket spending. Few participants voiced the need to know the precise cost of the visit upfront. Major concerns about e-visits included naming conventions, difficulty choosing the right visit type, and discomfort expressing medical terms in writing. A minority of participants expressed technical barriers to use of e-visits, and these included both participants who had and had not recently used the patient portal to receive care.

Concern about potential out-of-pocket costs was not a common theme among the participants in this study, and participants...
generally agreed that providers should receive payment for providing medical advice via web-based messages. This finding is important because it differs from the concerns raised in recent media coverage of e-visits, which has emphasized the implementation of billable messaging causing possible financial harm to patients [29,30]. However, this study was limited to mostly patients with Medicare insurance, so the absence of concern about out-of-pocket costs of e-visits may not be generalizable to other patient groups with different health insurance cost sharing structures.

Over the past several years, there has been a major increase in the number of patient portal messages, leading to burnout among frontline nurses, physicians, and other staff who must respond to these messages, largely between or after their other clinical duties and without reimbursement [31,32]. Billable e-visits are one potential solution. By reimbursing providers for delivering medical advice outside of a visit, e-visits may allow them to schedule more protected time during the day for responding to messages, rather than doing so on nights and weekends. They may also encourage care delivery organizations to innovate alternate means of communicating with and engaging patients. However, there is a risk that if organizations replace patient-portal messaging with billable e-visits, it will create a financial disincentive for patients to seek help when they need it. Therefore, the findings of this study are important, as they suggest that the majority of older adults are receptive to the concept of e-visits and do not perceive major financial barriers to use.

Older adults are at particular risk for facing health disparities as a result of decreased access to digital health technologies [33,34]. Our findings include perceptions of older adults and other groups at risk for health disparities, including those with limited English proficiency and of various races and ethnicities. Most participants in this study preferred synchronous communication over asynchronous methods like e-visits and unbilled patient portal messages, putting them at risk for ongoing disparities unless specific efforts are undertaken to make these tools attractive and accessible to them. Various interventions have been suggested for addressing the digital divide in general—for example, universal internet access, training in computer literacy, language concordant materials, and encouraging family or caregiver assistance in using digital tools [34]. In addition, we recommend several interventions below that are specific to e-visits.

Given recent changes in Centers for Medicare and Medicaid Services policy that allow for broader use of e-visits, many organizations may be considering implementing e-visits. However, there are several potential barriers to consider. The findings from our analysis, which includes the perspectives of a diverse group of older adults, may be generalizable to other institutions (Figure 1). We identified several key lessons learned that may inform interventions to improve acceptability and usability of e-visits. First, patients may not know what e-visits are or how to choose between an e-visit and a traditional patient portal message or other visit type. To address this, we recommend that the patient-facing name for e-visits be something more descriptive, such as “medical advice message.” We also recommend that patients not be asked to determine whether their message clinically qualifies as a billable e-visit or a nonbillable patient portal message—rather, that there should be a single point of entry for patients and billing should occur only if the message meets criteria. Third, patients may have technical, language, or educational barriers to using e-visits. We found that few participants actually lacked access to the necessary equipment but that many expressed discomfort using technology or expressing medical questions in writing. For this reason, we recommend that patients be able to write e-visit queries in their preferred language and with prompts (eg, are you having pain? What medications have you tried?) to improve comfort with phrasing medical questions in writing. Patient caregivers (eg, adult children) should be given proxy access to patient portals to submit e-visits on their behalf. Finally, patients may have concerns about receiving a bill for patient portal messages that are classified as e-visits if their patient portal communications had all been unbilled in the past. We recommend that organizations include a disclaimer in plain language that requires the patient’s acknowledgement, describing that some messages may be billed and may generate out-of-pocket costs to the patient. Ideally, organizations should also provide patients with the range or average out-of-pocket cost of these visits, acknowledging that they will vary by insurance type.

Our results align with published literature on patient perceptions of use of other virtual care options, such as patient portals (secure websites giving patients access to personal health information, including the ability to communicate with their care team) and chatbots. For example, a 2018 National Poll by the University of Michigan determined that the technology gaps for older adults were rapidly narrowing, but nonetheless, respondents older than 65 years were more likely to report that they did not like using the computer to communicate about their health [35]. Similarly, a systematic review of perceptions of patient portals [36] determined that patient-provider communication was the most prevalent positive attribute, while concerns over security and user-friendliness were the most prevalent negative perceptions. This sentiment aligns with our findings that participants perceived a benefit of e-visits being the ability to communicate with their physician asynchronously to avoid a visit, while a commonly cited barrier to use was navigating the patient portal to choose the appropriate visit type. This insight also supports the conclusion of a study from Sweden [37] in which patients who used a chat-based, automated history-taking service appreciated the ability to communicate medical information asynchronously and potentially prevent an unnecessary visit.
Limitations and Strength

This study has several limitations. First, because e-visits were not being frequently used at the time of the study, very few of the participants had used an e-visit before, so their perceptions were based on the description of this new visit type by the interviewer. Patients who have used an e-visit to receive care in the past may have different perceptions. Second, we interviewed a relatively small sample size of 20 patients, and the majority were from the San Francisco Bay Area, where there are high rates of digital literacy. Our findings may therefore not be generalizable to very different patient populations. However, with this study’s sample size and composition, we reached saturation of ideas in participants responses. Third, interpretation of transcription content may be biased due to individual reviewer’s implicit biases. However, neither of the reviewers had a direct role in overseeing e-visit implementation and had no financial or other incentives for e-visits being successful. Fourth, participant responses could have been more favorable due to social desirability bias since the research team is affiliated with the health care system in which they receive care [38]. However, the researchers were not on the patients’ treatment teams and explicitly stated prior to the interview that all responses would be anonymized and would in no way affect their care. Furthermore, gift cards to compensate participants’ time were distributed prior to the interview to prevent any misperception that certain responses would be linked to reward. Fifth, because we used open-ended questions, more time may have been spent discussing certain themes or categories than others, which may have created a bias in quantitative analysis if participant responses were a reflection more so of the questions asked than of their opinions about e-visits. Finally, our study population was identified among UCSF primary care patients who had used a patient portal or telephone triage tool to seek an appointment, testing, or triage advice about COVID-19. It is possible that these patients differed in some way from the general population, though we have no reason to suspect that this group would have different perceptions about virtual care.

The study also had several strengths. We recruited a group of participants with diverse personal characteristics, including race, ethnicity, language, income, and geography, to capture of range of experiences. We allotted up to 60 minutes for each interview to provide time for open responses and for participants to elaborate on their responses. We also recruited patients who had variable historic use of the patient portal, to capture the perceptions of those who may be less technically savvy with digital health tools.

Conclusion

In summary, this is one of the first studies to report qualitative feedback on e-visits, and the first, to our knowledge, to do so since the start of the COVID-19 pandemic and reflecting the 2020 changes Centers for Medicare and Medicaid Services policy changes related to e-visits. Our evaluation is an important step toward understanding patient perceptions around e-visits, a relatively new asynchronous form of digital health care delivery. Our findings suggest that older adults are generally accepting of the concept of e-visits, but still prefer synchronous visit types. We identified opportunities to improve e-visit implementation and design. As telemedicine and virtual care continue to grow and occupy a greater part of the health care landscape, issues such as patient acceptance, digital health care access, and usability in provider workflows will become increasingly critical to the success of such programs.
Acknowledgments
The authors would like to acknowledge Ralph Gonzales, MD, MSPH, and Jonathan Lee, MD, who helped to conceive the design of this study.

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Authors’ Contributions
TJJ, MS and JDH conceptualized the study. All authors contributed equally to the overall design of the study. TJJ and MS were responsible for the development of patient interview questionnaires. JY conducted the patient interviews. TJJ, MS, and JDH were involved in data analysis. TJJ and MS wrote the first draft of the manuscript, and all authors reviewed, edited, and contributed to subsequent revisions. Regarding data access, responsibility, and analysis, TJJ and MS had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of Interest
TJJ receives consulting fees from the McKinsey Clinical Network and has received equity from Assure Health. MB receives University of California copyright royalties for Copyright SF2015-137 and Patent SF2016-239.

Multimedia Appendix 1
Structured interview guide.

References


Abbreviations

UCSF: University of California, San Francisco

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Factors Predicting Older People’s Acceptance of a Personalized Health Care Service App and the Effect of Chronic Disease: Cross-Sectional Questionnaire Study

Jun Hyuk Koo¹, PhD; You Hyun Park², MSc; Dae Ryong Kang²,³, PhD

¹National Health BigData Clinical Research Institute, Yonsei University Wonju Industry-Academic Cooperation Foundation, Wonju, Republic of Korea
²Department of Biostatics, Yonsei University Graduate School, Wonju, Republic of Korea
³Department of Precision Medicine, Yonsei University Wonju College of Medicine, Wonju, Republic of Korea

Corresponding Author:
Dae Ryong Kang, PhD
Department of Precision Medicine
Yonsei University Wonju College of Medicine
20 Ilsan-ro
Wonju, 26426
Republic of Korea
Phone: 82 33 741 0391
Email: dr.kang@yonsei.ac.kr

Abstract

Background: Mobile health (mHealth) services enable real-time measurement of information on individuals’ biosignals and environmental risk factors; accordingly, research on health management using mHealth is being actively conducted.

Objective: The study aims to identify the predictors of older people’s intention to use mHealth in South Korea and verify whether chronic disease moderates the effect of the identified predictors on behavioral intentions.

Methods: A cross-sectional questionnaire study was conducted among 500 participants aged 60 to 75 years. The research hypotheses were tested using structural equation modeling, and indirect effects were verified through bootstrapping. Bootstrapping was performed 10,000 times, and the significance of the indirect effects was confirmed through the bias-corrected percentile method.

Results: Of 477 participants, 278 (58.3%) had at least 1 chronic disease. Performance expectancy (β=.453; P=.003) and social influence (β=.693; P<.001) were significant predictors of behavioral intention. Bootstrapping results showed that facilitating conditions (β=.325; P=.006; 95% CI 0.115-0.759) were found to have a significant indirect effect on behavioral intention. Multigroup structural equation modeling testing the presence or absence of chronic disease revealed a significant difference in the path of device trust to performance expectancy (critical ratio=–2.165). Bootstrapping also confirmed that device trust (β=.122; P=.039; 95% CI 0.007-0.346) had a significant indirect effect on behavioral intention in people with chronic disease.

Conclusions: This study, which explored the predictors of the intention to use mHealth through a web-based survey of older people, suggests similar results to those of other studies that applied the unified theory of acceptance and use of technology model to the acceptance of mHealth. Performance expectancy, social influence, and facilitating conditions were revealed as predictors of accepting mHealth. In addition, trust in a wearable device for measuring biosignals was investigated as an additional predictor in people with chronic disease. This suggests that different strategies are needed, depending on the characteristics of users.

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KEYWORDS
environmental risk factor; personalized health care service app; chronic disease; unified theory of acceptance and use of technology; structural equation modeling; older adult; acceptance; adoption; technology use; mHealth; mobile health; mobile app; health app; gerontology; personalized; health care service; intention to use
**Introduction**

**Background**

New medical strategies that aim to change individual behaviors and lifestyles are being introduced. These medical strategies are based on information and communications technology and the internet of things. Among these, mobile health (mHealth) apps are one type of strategy that allows us to perform tasks such as modernizing data acquisition analysis for clinical trials, facilitating behavior change among users, disease management, self-diagnosis, improving patients’ confidence and satisfaction, and reducing health care costs [1-4].

Several studies have examined the use of mHealth for environmental health impact assessments—assessment of health-related problems deriving from the environment, such as chemical hazards, environmental contaminants, and other aspects of the ambient and living environment [5]. For example, Karagiannaki et al [6] deployed mHealth to monitor environmental factors affecting maternal health remotely. Honkoop et al [7] predicted the onset of asthma according to physiological, behavioral, and environmental data obtained by mHealth and home-monitoring sensors. Another study emphasized the importance of integrating location-based services into mHealth platforms to evaluate exposure to air pollutants [8]. As these examples show, mHealth is being actively used to promote human health in the context of environmental risk.

Using mHealth alongside medical prescriptions for older adults is more effective than traditional methods of managing their health [9]. mHealth positively influences health behavior, including improving physical activity, normalizing BMI, and decreasing sedentariness [10-12]. Although older people know the benefits of improving health behaviors, they tend not to pursue such improvements. In such cases, mHealth can facilitate older people’s healthy behavior through notifications that serve as reminders [13,14]. Furthermore, older people need to extend their health span through continuous and systematic health management [15]; managing chronic diseases is the most important and fundamental aspect in this regard. mHealth is also effective for people with chronic diseases [16,17]. One study proved that mHealth was useful in meeting older people’s information needs, especially concerning health, and was entirely accepted as a tool for monitoring health status and changing behavior [18]. Clearly, the evidence suggests that mHealth is an effective means of health management for older people and that the efforts should be focused on increasing its usage. Thus, studying the acceptability of mHealth usage among older people is important. In this study, we examine the acceptability of a personalized health care service app that we are currently developing.

Research on technology acceptance commonly uses the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT). TAM [19] is widely used in research that primarily addresses the intention to use information and communications technology; it assesses a person’s attitude toward using the system, its perceived usefulness (PU), and its perceived ease of use (PEOU). Attitude directly affects behavioral intention to use the system, and PU and PEOU indirectly affect behavioral intention by directly affecting attitude. UTAUT [20] is a model developed by analyzing and comparing 8 models related to behavioral intention; in this model, performance expectancy, effort expectancy, and social influence affect behavioral intention, whereas behavioral intention and facilitating conditions affect use behavior. Unlike TAM, the UTAUT does not include “attitude” in the model.

**Personalized Health Care Service App**

The personalized health care service app we are developing aims to facilitate early identification and management of the health effects of exposure to real-time environmental risk factors. It provides health status reports and hospital visit recommendations based on the user’s biosignals and surrounding environment information. Biosignals such as electrocardiograms and heart rates are measured by wearable devices and linked with the app. Our app also assesses concentrations of hazardous substances in the air as environmental risk factors. It contains the values for particular matter (PM<sub>2.5</sub>, PM<sub>10</sub>), ozone, nitrogen dioxide, carbon monoxide, and sulfur dioxide. Instead of individually measuring the concentration of environmental risk factors, our design measures concentration data every minute using real-time personal location information based on the global positioning system combined with information from environmental harmful factor concentration stations in Korea. The app also provides information about health risks by considering individual health status (sociodemographic variables, individual medical checkups, diagnostic records, etc) and identifying correlations between environmental exposure and health effects. Furthermore, the app provides regular health analysis reports, information about nearby hospitals, recommendations for appropriate actions in the event of a health hazard, and so forth.

**Objective**

This study aims to identify predictors of older people’s intention to use the personalized health care service app and to verify whether chronic disease moderates the effect on behavioral intentions using the extended UTAUT model.

**Methods**

**Research Model and Research Hypotheses**

We used the latent variables of performance expectancy, effort expectancy, social influence, and facilitating conditions from UTAUT [20]. UTAUT addresses actual use behavior; thus, facilitating conditions are set as variables that affect use behavior but not behavioral intention. However, since the app in this study is in the development stage and has not been released, use behavior cannot yet be measured. In the later UTAUT2 model developed by Venkatesh et al [21], facilitating conditions are extended to include factors affecting behavioral intention and use behavior. To receive customized services through the app, it is essential to use a wearable device to measure biosignals. Therefore, we also included device trust in our research model.
Performance expectancy is defined as “the degree to which individuals believe that using the personalized health management service app will help improve their health” [20]; this construct is similar to PU in the TAM [19]. Many previous studies on accepting health care services have demonstrated that performance expectancy is a good predictor of behavioral intention [22-35]. Thus, we proposed the following hypothesis.

**H1:** Performance expectancy will have a significant positive influence on behavioral intention.

Effort expectancy is also an essential predictor of behavioral intention; it refers to “the degree of ease associated with the use of the personalized health management service app” [20] and is similar to PEOU in the TAM [19]. The relationship between effort expectancy and behavioral intention has been confirmed in many studies [24-33,36]. Although the UTAUT model differs from TAM, assuming that effort expectancy does not affect performance expectancy, we can intuitively say that user-friendly and accessible services feel more useful. Indeed, consistent evidence shows a significant relationship between effort expectancy and performance expectancy [23-26,34,37,38]. Accordingly, we hypothesized the following.

**H2:** Effort expectancy will have a significant positive influence on behavioral intention.

**H3:** Effort expectancy will have a significant positive influence on performance expectancy.

Facilitating conditions are defined as “the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the personalized health management service app” [20]. In some cases, facilitating conditions are divided into resource and technological aspects [26]. In this study, we considered technological facilitating conditions at the organizational level. Particularly, older people unfamiliar with the new technology are more likely to try to use it if they have the support of a service provider. Previous studies have shown that facilitating conditions may affect behavioral intention [26-31,34]. Additionally, from the perspective of gerontechnology—which helps older people lead a consistently healthier, more independent, and more socially engaged life—a study predicted that facilitating conditions will affect performance expectancy [38]. From the health management perspective, some studies showed that facilitating conditions can influence performance expectancy [26,32,34,38]. Taking these points together, we proposed the following 2 hypotheses.

**H4:** Facilitating conditions will have a significant positive influence on behavioral intention.

**H5:** Facilitating conditions will have a significant positive influence on performance expectancy.

Social influence refers to “the degree to which an individual perceives that important others believe he or she should use the personalized health management service app” [20]. If people who are important to target users want them to use particular services, their usage likelihood increases. In particular, this influence may be more decisive when their knowledge about the service is insufficient or when the service is unfamiliar. Many studies have shown that social influence can be one of the good predictors of behavioral intention [25-29,32-34,37]. Accordingly, we hypothesized the following.

**H6:** Social influence will have a significant positive influence on behavioral intention.

Device trust is defined as “the degree to which individuals believe that they are confident in the quality and reliability of wearable devices” [39]. Although many studies have verified the accuracy and reliability of wearable devices from the perspective of precision medicine, there are relatively few studies on their technological acceptance [36]. Considering the technology behind wearable medical devices has reached a certain level of maturity, we need to pay attention to other aspects. In particular, if users can trust the measurement function and security of wearable devices, their intention to use the health care service will increase. Several studies have shown that trust in products or services has a positive effect on behavioral intention toward new technology [24,27,37]. Our app will provide personalized services based on biosignals measured by wearable devices. Therefore, those who trust wearable devices should be more likely to evaluate this service model as useful [40]. Several similar studies have found positive relationships between trust and performance expectancy [25,37,41]. Accordingly, we hypothesized the following.

**H7:** Device trust will have a significant positive influence on performance expectancy.

**H8:** Device trust will have a significant positive influence on behavioral intention.

It is widely known that people with chronic diseases are more vulnerable to environmental risk factors such as air pollution [42,43]. Furthermore, patients with chronic disease are more likely to use health system portals and to track health indicators [44]. Therefore, we assumed that patients with chronic disease would show more interest in using health care services for health management than other patients. Moreover, since patients with chronic disease periodically measure and manage their biosignals, such as blood pressure and blood sugar, they would be more accustomed to biosignal measurement. Accordingly, we hypothesized the following:

**H9-H11:** The influences of performance expectancy on behavioral intention (H9), device trust on behavioral intention (H10), and device trust on performance expectancy (H11) are moderated by the presence or absence of chronic diseases, such that the influences will be stronger for people who have chronic diseases.

In summary, the proposed research model is shown in Figure 1.
Data Collection
The web-based survey was conducted from June 27 to July 4, 2022, by the survey company dataSpring. The sample size was calculated using an a priori sample size calculator for structural equation modeling (SEM) [45]. The minimum recommended sample size was 200 cases based on 6 latent and 19 observed variables, with an anticipated effect size of 0.3, a desired statistical power level of 0.9, and a probability level of .05.

The study’s target group comprised people aged between 60 and 75 years and who are vulnerable to environmental risk factors. We recruited a sample of 500 participants to perform a multigroup analysis. The survey was first conducted on 290 people with chronic diseases, recruited using convenience sampling; subsequently, 210 people without chronic diseases were surveyed by matching the intergroup gender and age ratios as much as possible.

Only individuals who read the description of the research before the survey and voluntarily agreed to participate were selected as study participants. Before answering the questionnaire, they watched a video explaining the functionality of the personalized health care service app, which took about 4 minutes.

Ethics Approval
This study was conducted after receiving ethical approval from the institutional review board of Yonsei University Wonju Severance Christian Hospital (CR322027).

Questionnaire Development
All questionnaire items were constructed based on previous studies (see Multimedia Appendix 1). The measurement variables used in the research model were scored on 5-point Likert scales ranging from 1="strongly disagree" to 5="strongly agree." Additionally, information about gender, age, residential area, final educational background, and presence of chronic disease were collected. Residential areas were divided into metropolitan areas (Seoul, Incheon, and Gyeonggi) and others. A person with chronic disease was defined as “someone who has been diagnosed by a doctor and has been regularly under treatment or taking medication for at least three months”;

participants were asked to self-report the presence of chronic diseases.

Statistical Analysis
First, the general characteristics of the survey respondents were confirmed through frequency analysis. Subsequently, we verified the research model’s convergent and discriminant validity. Convergent validity was confirmed using factor loading, average variance extracted (AVE), and construct reliability values obtained through confirmatory factor analysis. Two methods were used to test the model’s discriminant validity. The first involved testing whether the construct’s square root value of AVE was greater than its correlation with any other constructs [46]. The second involved testing whether the range of adding or subtracting the SE of covariance multiplied by 2 to the correlation coefficient between 2 latent variables did not include 1 [47,48]. Additionally, to verify the cross-validation between the chronic disease and nonchronic disease groups, an analysis of measurement equivalence was conducted.

Then, SEM—a method used to statistically verify relationships defined in a theoretical framework using the covariance or correlation matrixes of the data—was performed to verify the research hypotheses. The analysis was performed using maximum likelihood estimation, and the model fit was confirmed through the absolute and incremental fit indexes. For the former, normed chi-square, goodness-of-fit index, and root-mean-square error of approximation were used. For the latter, Tucker-Lewis index, comparative fit index, and normed fit index were used. Subsequently, the critical ratio for differences was confirmed by restricting each pathway to verify the moderating effect of chronic diseases. Bootstrapping using the maximum likelihood method was repeated 10,000 times to confirm the statistical significance of the model’s indirect effects. Finally, statistical significance and confidence limits were obtained with the bias-corrected percentile method [49]. All statistical analyses were performed using SPSS Statistics 26.0 and SPSS Amos 28.0 Graphics (IBM Corp).
Results

General Respondent Characteristics

The descriptive statistics for respondents’ characteristics are shown in Table 1. Among 500 participants, the responses of 23 participants were discarded due to poor data quality, such as straight-lined answers. Given the methodological procedure described above (in which nonchronic disease participants were recruited after those with chronic diseases and were matched for gender and age), there were no statistically significant differences between the 2 groups according to gender or age. Additionally, we found no statistically significant differences between the groups in terms of residential area and educational background.

Table 1. Descriptive statistics for respondents’ characteristics.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total, n (%)</th>
<th>CDa</th>
<th>No CD</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>477 (100)</td>
<td>278 (58.3)</td>
<td>199 (41.7)</td>
<td>N/Ab</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>276 (57.9)</td>
<td>164 (59.4)</td>
<td>112 (40.6)</td>
<td>.55</td>
</tr>
<tr>
<td>Female</td>
<td>201 (42.1)</td>
<td>114 (56.7)</td>
<td>87 (43)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td></td>
<td></td>
<td></td>
<td>.63</td>
</tr>
<tr>
<td>60-64, n (%)</td>
<td>280 (58.7)</td>
<td>159 (56.8)</td>
<td>121 (43.2)</td>
<td></td>
</tr>
<tr>
<td>65-69, n (%)</td>
<td>150 (31.4)</td>
<td>89 (59.3)</td>
<td>61 (41)</td>
<td></td>
</tr>
<tr>
<td>70-75, n (%)</td>
<td>47 (10)</td>
<td>30 (63.8)</td>
<td>17 (36)</td>
<td></td>
</tr>
<tr>
<td>Continuous mean (SD)</td>
<td>64.31 (3.42)</td>
<td>64.46 (3.47)</td>
<td>64.09 (3.36)</td>
<td>.23</td>
</tr>
<tr>
<td>Residential area, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.92</td>
</tr>
<tr>
<td>Metropolitan areas</td>
<td>308 (64.6)</td>
<td>180 (58.4)</td>
<td>128 (41.6)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>169 (35.4)</td>
<td>98 (58)</td>
<td>71 (42)</td>
<td></td>
</tr>
<tr>
<td>Educational background, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.69</td>
</tr>
<tr>
<td>High school or lower</td>
<td>152 (31.9)</td>
<td>91 (59.9)</td>
<td>61 (40)</td>
<td></td>
</tr>
<tr>
<td>College or university</td>
<td>274 (57.4)</td>
<td>160 (58.4)</td>
<td>114 (41.6)</td>
<td></td>
</tr>
<tr>
<td>Graduate school</td>
<td>51 (11)</td>
<td>27 (53)</td>
<td>24 (47)</td>
<td></td>
</tr>
<tr>
<td>Chronic diseases, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Yes</td>
<td>278 (58.3)</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>199 (41.7)</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

aCD: chronic diseases.
bN/A: not applicable.

Validity Analyses

Convergent Validity

The results of the confirmatory factor analysis are shown in Table 2. According to Hulland [50], the value of standardized factor loading is recommended to be 0.7 or higher. Bagozzi and Yi [51] suggested that the construct reliability and AVE values should be greater than or equal to 0.7 and 0.5, respectively. With these criteria, confirmatory factor analysis confirmed the convergent validity of our model.
Table 2. Confirmatory factor analysis.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Estimate</th>
<th>SE</th>
<th>Critical ratio</th>
<th>P value</th>
<th>AVE\textsuperscript{a}</th>
<th>CR\textsuperscript{b}</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE\textsuperscript{c}</td>
<td>0.89</td>
<td>0.74</td>
<td>—\textsuperscript{d}</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>PE1</td>
<td>0.70</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>PE2</td>
<td>0.82</td>
<td>1.30</td>
<td>0.08</td>
<td>16.19</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>PE3</td>
<td>0.84</td>
<td>1.21</td>
<td>0.07</td>
<td>16.67</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>EE\textsuperscript{e}</td>
<td>0.68</td>
<td>0.89</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>EE1</td>
<td>0.69</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>EE2</td>
<td>0.80</td>
<td>1.39</td>
<td>0.09</td>
<td>15.49</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>EE3</td>
<td>0.79</td>
<td>1.41</td>
<td>0.09</td>
<td>15.39</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>EE4</td>
<td>0.79</td>
<td>1.40</td>
<td>0.09</td>
<td>15.41</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>FC\textsuperscript{f}</td>
<td>0.68</td>
<td>0.86</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>FC1</td>
<td>0.70</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>FC2</td>
<td>0.78</td>
<td>1.21</td>
<td>0.08</td>
<td>15.34</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>FC3</td>
<td>0.80</td>
<td>1.27</td>
<td>0.08</td>
<td>15.70</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>SI\textsuperscript{g}</td>
<td>0.67</td>
<td>0.86</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SI1</td>
<td>0.71</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SI2</td>
<td>0.75</td>
<td>1.15</td>
<td>0.08</td>
<td>15.16</td>
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<td>—</td>
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<tr>
<td>SI3</td>
<td>0.81</td>
<td>1.27</td>
<td>0.08</td>
<td>16.10</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>DT\textsuperscript{h}</td>
<td>0.62</td>
<td>0.83</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>DT1</td>
<td>0.69</td>
<td>1.00</td>
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<td>—</td>
</tr>
<tr>
<td>DT2</td>
<td>0.71</td>
<td>1.29</td>
<td>0.10</td>
<td>13.18</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>DT3</td>
<td>0.79</td>
<td>1.35</td>
<td>0.10</td>
<td>14.16</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>BI\textsuperscript{i}</td>
<td>0.77</td>
<td>0.91</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>BI1</td>
<td>0.83</td>
<td>1.00</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>BI2</td>
<td>0.83</td>
<td>1.09</td>
<td>0.06</td>
<td>19.56</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
<tr>
<td>BI3</td>
<td>0.79</td>
<td>1.02</td>
<td>0.06</td>
<td>18.62</td>
<td>&lt;.001</td>
<td>—</td>
</tr>
</tbody>
</table>

\textsuperscript{a}AVE: average variance extracted. \\
\textsuperscript{b}CR: construct reliability. \\
\textsuperscript{c}PE: performance expectancy. \\
\textsuperscript{d}Not available. \\
\textsuperscript{e}EE: effort expectancy. \\
\textsuperscript{f}FC: facilitating conditions. \\
\textsuperscript{g}SI: social influence. \\
\textsuperscript{h}DT: device trust. \\
\textsuperscript{i}BI: behavioral intention.

**Discriminant Validity**

The discriminant validity was tested in 2 ways. Table 3 shows the results of the first method, which compares the correlation coefficient of the latent variables and the square root of AVE. Although discriminant validity was generally satisfied, we found that some correlation coefficients were higher than the square root of AVE. Next, discriminant validity was reconfirmed by the second method, using performance expectancy and social influence, which had the highest correlation coefficients. The correlation coefficient between them was 0.866, and the SE of covariance was 0.024; therefore, we confirmed that the range of adding or subtracting the SE multiplied by 2 to the correlation coefficient did not include 1.
Table 3. Discriminant validity analysis.

<table>
<thead>
<tr>
<th></th>
<th>PE&lt;sup&gt;a&lt;/sup&gt;</th>
<th>EE&lt;sup&gt;b&lt;/sup&gt;</th>
<th>FC&lt;sup&gt;c&lt;/sup&gt;</th>
<th>SI&lt;sup&gt;d&lt;/sup&gt;</th>
<th>DT&lt;sup&gt;e&lt;/sup&gt;</th>
<th>BI&lt;sup&gt;f&lt;/sup&gt;</th>
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</thead>
<tbody>
<tr>
<td>PE</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE</td>
<td>0.75</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FC</td>
<td>0.87</td>
<td>0.76</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SI</td>
<td>0.87</td>
<td>0.71</td>
<td>0.85</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT</td>
<td>0.73</td>
<td>0.64</td>
<td>0.76</td>
<td>0.78</td>
<td>1</td>
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</tr>
<tr>
<td>BI</td>
<td>0.72</td>
<td>0.53</td>
<td>0.65</td>
<td>0.77</td>
<td>0.65</td>
<td>1</td>
</tr>
<tr>
<td>Sqrt of AVE&lt;sup&gt;g&lt;/sup&gt;</td>
<td>0.86</td>
<td>0.83</td>
<td>0.82</td>
<td>0.82</td>
<td>0.79</td>
<td>0.88</td>
</tr>
</tbody>
</table>

<sup>a</sup>PE: performance expectancy.
<sup>b</sup>EE: effort expectancy.
<sup>c</sup>FC: facilitating conditions.
<sup>d</sup>SI: social influence.
<sup>e</sup>DT: device trust.
<sup>f</sup>BI: behavioral intention.
<sup>g</sup>Sqrt of AVE: square root of average variance extract.

**Cross-Validity**

The verification of measurement equivalence was performed through multigroup confirmatory factor analysis. To confirm the difference between the unconstrained and factor-loading constrained models, we used the difference between their chi-square values. The chi-square value of the unconstrained model was 591.4, and the degree of freedom was 274; for the factor loading constrained model, the values were 603.9 and 287, respectively. Since the threshold of the chi-square value at the degree of freedom of 13 was 22.4, there was no statistically significant difference in factor loading between the 2 groups for the measurement tool.

**Hypotheses Testing**

We performed SEM to test our research hypotheses. Table 4 shows that H1, H5, and H6 were supported. That is, participants who stated that performance expectancy and social influence were important were more likely to believe with behavioral intentions to use mHealth, and people who thought that facilitating conditions was important were more likely to believe performance expectancy was also important. Bootstrapping was performed 10,000 times to check whether there was an indirect effect, whereby facilitating conditions affected behavioral intention through performance expectancy. Assessing the statistical significance using the bias-corrected percentile method showed that the standardized indirect effect of facilitating conditions on behavioral intention was 0.325, the significance probability 0.006, and the 95% CI of 0.115-0.759, confirming a significant indirect effect.

The model fit of SEM was confirmed through normed chi-square, goodness-of-fit index, and root mean squared error of approximation (absolute fit index), Tucker-Lewis index, comparative fit index, and normed fit index (incremental fit index). Therefore, we confirmed that the recommended values suggested in previous studies were generally satisfied (Table 5).

The results of multigroup SEM analysis are shown in Table 6. The significance of the path difference between groups can be confirmed by looking at the critical ratio for differences. If the absolute value of the critical ratio is 1.965 or higher, there is a statistically significant difference in the path coefficients between groups. As the critical ratio for differences in hypothesis 11 was –2.165, there is a statistically significant difference between the 2 groups in the effect of device trust on performance expectancy. Whether there was an indirect effect of device trust on behavioral intention through performance expectancy in the chronic disease group was also confirmed through bootstrapping. Results found that the standardized indirect effect of device trust on behavioral intention was 0.122, the probability of significance 0.039, and 95% CI of 0.007-0.346, confirming that device trust has a significant indirect effect on behavioral intention in the chronic disease group.
Table 4. Verification of the research hypotheses.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Path</th>
<th>$\beta$</th>
<th>Estimate</th>
<th>SE</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>PE$^a$→BI$^b$</td>
<td>.453</td>
<td>0.538</td>
<td>0.179</td>
<td>.003</td>
</tr>
<tr>
<td>H2</td>
<td>EE$^c$→BI</td>
<td>-.097</td>
<td>-0.118</td>
<td>0.097</td>
<td>.23</td>
</tr>
<tr>
<td>H3</td>
<td>EE→PE</td>
<td>.116</td>
<td>0.120</td>
<td>0.070</td>
<td>.09</td>
</tr>
<tr>
<td>H4</td>
<td>FC$^{d}$→BI</td>
<td>-.338</td>
<td>-0.385</td>
<td>0.265</td>
<td>.15</td>
</tr>
<tr>
<td>H5</td>
<td>FC→PE</td>
<td>.716</td>
<td>0.686</td>
<td>0.099</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>H6</td>
<td>SI$^{e}$→BI</td>
<td>.693</td>
<td>0.776</td>
<td>0.197</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>H7</td>
<td>DT$^{f}$→BI</td>
<td>.089</td>
<td>0.107</td>
<td>0.114</td>
<td>.35</td>
</tr>
<tr>
<td>H8</td>
<td>DT→PE</td>
<td>.122</td>
<td>0.123</td>
<td>0.074</td>
<td>.10</td>
</tr>
</tbody>
</table>

$^a$PE: performance expectancy.
$^b$BI: behavioral intention.
$^c$EE: effort expectancy.
$^d$FC: facilitating conditions.
$^e$SI: social influence.
$^f$DT: device trust.

Table 5. Model fit.

<table>
<thead>
<tr>
<th>Model fit measure</th>
<th>Value</th>
<th>Recommended value</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normed $\chi^2$ $^a$</td>
<td>3.4</td>
<td>≤3</td>
<td>Acceptable</td>
<td>Hair et al [52]</td>
</tr>
<tr>
<td>GFI$^b$</td>
<td>0.9</td>
<td>&gt;0.90</td>
<td>Acceptable</td>
<td>Hair et al [52]</td>
</tr>
<tr>
<td>RMSEA$^c$</td>
<td>0.1</td>
<td>&lt;0.08</td>
<td>Good</td>
<td>Hair et al [52]</td>
</tr>
<tr>
<td>TLI$^d$</td>
<td>0.9</td>
<td>&gt;0.90</td>
<td>Good</td>
<td>Bentler et al [53]</td>
</tr>
<tr>
<td>CFI$^e$</td>
<td>0.9</td>
<td>&gt;0.90</td>
<td>Good</td>
<td>Hair et al [52]</td>
</tr>
<tr>
<td>NFI$^f$</td>
<td>0.9</td>
<td>&gt;0.90</td>
<td>Good</td>
<td>Bentler et al [53]</td>
</tr>
</tbody>
</table>

$^a$χ$^2_{138}$=463.3.
$^b$GFI: goodness-of-fit index.
$^c$RMSEA: root mean squared error of approximation.
$^d$TLI: Tucker-Lewis index.
$^e$CFI: comparative fit index.
$^f$NFI: normed fit index.
Table 6. Verification of the research hypotheses on the moderating effect.

<table>
<thead>
<tr>
<th>Hypothesis (path) and group</th>
<th>$\beta$</th>
<th>Estimate</th>
<th>SE</th>
<th>P-value</th>
<th>Critical ratio for differences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H9 (PE$^a \rightarrow$BI$^b$)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD$^c$</td>
<td>0.438</td>
<td>0.516</td>
<td>0.188</td>
<td>0.006</td>
<td>−0.934</td>
</tr>
<tr>
<td>No CD</td>
<td>0.429</td>
<td>0.508</td>
<td>0.393</td>
<td>0.429</td>
<td></td>
</tr>
<tr>
<td><strong>H10 (DT$^d \rightarrow$BI)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.780</td>
</tr>
<tr>
<td>CD</td>
<td>0.060</td>
<td>0.069</td>
<td>0.146</td>
<td>0.060</td>
<td></td>
</tr>
<tr>
<td>No CD</td>
<td>0.215</td>
<td>0.277</td>
<td>0.224</td>
<td>0.215</td>
<td></td>
</tr>
<tr>
<td><strong>H11 (DT$\rightarrow$PE)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>−2.165</td>
</tr>
<tr>
<td>CD</td>
<td>0.278</td>
<td>0.272</td>
<td>0.083</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>No CD</td>
<td>−0.100</td>
<td>−0.107</td>
<td>0.154</td>
<td>0.487</td>
<td></td>
</tr>
</tbody>
</table>

$^a$PE: performance expectancy.
$^b$BI: behavioral intention.
$^c$CD: chronic disease.
$^d$DT: device trust.

Discussion

Principal Results

This study identified the predictors of acceptance of a personalized health care service app by conducting SEM on questionnaire survey data collected from older adults aged 60 to 75 years. Performance expectancy ($\beta=0.453; P=0.003$) and social influence ($\beta=0.693; P<0.001$) were identified as significant predictors. Furthermore, bootstrapping analysis confirmed that facilitating conditions ($\beta=0.325; P=0.006; 95\% CI 0.115-0.759$) had an indirect effect on behavioral intention. Differences between groups according to the presence or absence of chronic diseases were confirmed through multigroup SEM. Additionally, device trust ($\beta=0.122; P=0.039; 95\% CI 0.007-0.346$) was found to have a significant indirect effect on behavioral intention in patients with chronic disease.

Comparison With Prior Work

As expected, performance expectancy was a significant predictor of the intention to use the personalized health care service app. These results were in line with many previous studies on the intention to use health care–related services [22-35]. Performance expectancy can be increased if it is possible to integrate mHealth services, with an existing health tracking app or a health information app that includes medication, treatment, and health checkup histories or hospital information such as the nearest hospital or reservation service. Park et al [29] emphasized the importance of effectively expressing the causal relationship between personal health records and physiological conditions and providing immediate feedback from health experts for encouragement to use a health care app. Another study suggested that mHealth apps should be integrated with other applications [28]. Notably, the results of a previous study indicate that performance expectancy has an important effect on the behavioral intention of people who have never used the service [54].

In line with several studies [22,23,35,37,41], we could not find evidence for effort expectancy’s effect on behavioral intention. The lack of direct effect might be because our survey design targeted people in the preuse stage [23,35]. Another study that found no effect of effort expectancy suggested the following explanation: their study sample was already familiar with the service, so variance according to effort expectancy was minimal [37]. In this study, although the service was explained through a description of the research and an introductory video, it may have been difficult for respondents to judge how much effort would actually be required.

Facilitating conditions were not a predictor of behavioral intention but did affect performance expectancy. We confirmed that facilitating conditions have an indirect effect on behavioral intention through performance expectancy. Some studies have revealed that facilitating conditions have an indirect effect on behavioral intention through performance expectancy [26,32,34]. In other words, if there is support from the service provider, the user may feel that the service is more useful. Since the participants in this study are older people who are unfamiliar with new technology, the facilitative infrastructure of service providers is important. One study showed that performance expectancy was relatively more important than facilitating conditions in a group that had not yet experienced the service [54]. However, in the case of the group with experience in using the service, the importance of facilitating conditions was relatively high. With the previous study’s results in mind, it would be interesting to investigate any changes in our results after our mHealth app has been put into actual use.

Social influence was also an essential predictor of the intention to use the service model; this supports previous studies dealing with similar topics to ours, which have reported that social influence positively affects behavioral intention [22,30,31,35]. There are several possible explanations, though 1 important reason could be the cultural context. Older people’s decisions regarding health care may be more influenced by their families than by themselves; the influence of the family is particularly
prominent in Confucian culture [55]. For this reason, the personalized health care service app will need to be promoted at the family and community levels in such cultures especially.

Finally, we confirmed that trust in wearable devices affects performance expectancy in the group with chronic diseases. Through this, we proved that device trust could be one of the predictors that indirectly affected behavioral intention. Artificial intelligence–based health care management services using biosignal measurement and wearable devices are known to be safe and cost-effective for managing chronic diseases [56]. Thus, in the early stage of service introduction, the project should specifically target older people with chronic diseases vulnerable to environmental risk factors. Improving their performance expectancy would be helpful, highlighting the accuracy and reliability of wearable devices.

Limitations
In this study, discriminant validity was verified in 2 ways. There were some ambiguities in comparison with the correlation coefficient between latent variables and the square root of AVE. These can be solved by merging the corresponding latent variables or removing some [57]; however, this method is not desirable when the research model is built based on a particular theory [48]. Since UTAUT is a very widely used theory, we decided to accept the conclusion gained using the second method of testing discriminant validity used in this study. In future studies, better results could be obtained to reduce measurement errors.

The mHealth app, which we are developing, does not target a specific chronic disease. Therefore, in this study, the definition of “chronic disease” has been set broadly. There are various types of chronic diseases, and the methods and levels of their management are also different. More detailed research can be done on mHealth for the management of specific chronic diseases.

Additionally, since this study was designed as a cross-sectional survey and random sampling was not applied, the generalizability of the results is limited. The personalized health care service app introduced in this study is currently under development; the goal is to develop it into a more user-friendly service through continuous research on the attitudes of potential users. Furthermore, continuous research, which can better represent the population, will further strengthen the explanatory power of the model proposed in this study.

Conclusions
Performance expectancy, social influence, and facilitating conditions are predictors of the intention to use mHealth among older people vulnerable to environmental risk factors. It is important to demonstrate and highlight the benefits of personalized health care services for health management to encourage older people to use them. The awareness of people around the target users also plays an important role. In particular, it is necessary to promote such services at the family and community levels; this aspect is critical in the Confucian culture. In addition, support from service providers should be strengthened so that older people can trust that they have consistent access to technical support. Furthermore, our findings suggest that different strategies should be used depending on the presence or absence of chronic disease. The reliability of biosignal measurements made by wearable devices should be emphasized to achieve a higher usage rate among older people with chronic diseases.

Acknowledgments
This work was supported by the Korea Environmental Industry and Technology Institute through the Development of a Personalized Service Model for Management of Exposure to Environmental Risk Factors among Vulnerable and Susceptible Individuals program, funded by the Korean Ministry of Environment (2021003340003).

Conflicts of Interest
None declared.

Multimedia Appendix 1
Overview of the instrument.
[DOCX File, 25 KB - aging_v6i1e41429_app1.docx ]

References


9. Changizi M, Kaveh MH. Effectiveness of the mHealth technology in improvement of healthy behaviors in an elderly population-a systematic review. Mhealth 2017;3:51 [FREE Full text] [doi: 10.21037/mjir.2017.08.06] [Medline: 29430455]


25. Faqih KMS, Jaradat MIRM. Mobile healthcare adoption among patients in a developing country environment: exploring the influence of age and gender differences. IBR 2015;8(9):142-174 [FREE Full text] [doi: 10.5539/ibr.v8n9p142]


**Abbreviations**

- AVE: average variance extracted
- mHealth: mobile health
- PEOU: perceived ease of use
- PU: perceived usefulness
- SEM: structural equation modeling
- TAM: technology acceptance model
- UTAUT: unified theory of acceptance and use of technology

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Robots in Assisted Living Facilities: Scoping Review

Katie Trainum1, BSN, RN; Rachel Tunis2, BA; Bo Xie1,2, BSc, MSc, PhD; Elliott Hauser2, PhD

1School of Nursing, The University of Texas at Austin, Austin, TX, United States
2School of Information, The University of Texas at Austin, Austin, TX, United States

Corresponding Author:
Katie Trainum, BSN, RN
School of Nursing
The University of Texas at Austin
1710 Red River St.
Austin, TX, 78712
United States
Phone: 1 512 471 7913
Email: katie.trainum@utexas.edu

Abstract

Background: Various technological interventions have been proposed and studied to address the growing demand for care of residents in assisted living facilities, in which a preexisting shortage of professional caregivers has been exacerbated by the COVID-19 pandemic. Care robots are one such intervention with the potential to improve both the care of older adults and the work life of their professional caregivers. However, concerns about efficacy, ethics, and best practices in the applications of robotic technologies in care settings remain.

Objective: This scoping review aimed to examine the literature on robots used in assisted living facilities and identify gaps in the literature to guide future research.

Methods: On February 12, 2022, following the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) protocol, we searched PubMed, CINAHL Plus with Full Text, PsycINFO, IEEE Xplore digital library, and ACM Digital Library using predetermined search terms. Publications were included if they were written in English and focused on the use of robotics in assisted living facilities. Publications were excluded if they did not provide peer-reviewed empirical data, focused on user needs, or developed an instrument to study human-robot interaction. The study findings were then summarized, coded, and analyzed using the Patterns, Advances, Gaps, Evidence for practice, and Research recommendations framework.

Results: The final sample included 73 publications from 69 unique studies on the use of robots in assisted living facilities. The findings of studies on older adults were mixed, with some studies suggesting positive impacts of robots, some expressing concerns about robots and barriers to their use, and others being inconclusive. Although many therapeutic benefits of care robots have been identified, methodological limitations have weakened the internal and external validity of the findings of these studies. Few studies (18/69, 26%) considered the context of care: most studies (48/69, 70%) collected data only on recipients of care, 15 studies collected data on staff, and 3 studies collected data on relatives or visitors. Theory-driven, longitudinal, and large sample size study designs were rare. Across the authors’ disciplines, a lack of consistency in methodological quality and reporting makes it difficult to synthesize and assess research on care robotics.

Conclusions: The findings of this study call for more systematic research on the feasibility and efficacy of robots in assisted living facilities. In particular, there is a dearth of research on how robots may change geriatric care and the work environment within assisted living facilities. To maximize the benefits and minimize the consequences for older adults and caregivers, future research will require interdisciplinary collaboration among health sciences, computer science, and engineering as well as agreement on methodological standards.

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KEYWORDS

robotics; long-term care; nursing home; residential care; scoping review; review method; robot; aging; elder; older adult; gerontology; geriatric; senior living
Introduction

There is a severe need to provide quality care for the world’s growing population of older adults and to improve the work environments of their professional caregivers. In the United States, the population aged ≥65 years is projected to increase from 49 million in 2016 to 95 million in 2060 [1], and adults in the United States aged ≥65 years have a 70% chance of eventually requiring some type of long-term care [2]. A study conducted since the start of the COVID-19 pandemic found that 99% of nursing homes and 96% of assisted living facilities in the United States are facing staffing shortages [3]. With >14% of their workforce lost since February 2020, nursing homes have been forced to limit new patient admissions, thus preventing older adults from accessing care [4]. The growing population of older adults, coupled with current caregiver shortages, has led to a severe mismatch between the individuals who need care and those who provide it.

Much effort has been devoted to developing technological interventions to ameliorate the mismatch between care needs and the capacity and quality of care for older adults. An increasing number of robotics and gerotechnology researchers are designing, developing, and evaluating care robots to provide physical assistance and social support to older adults and their caregivers [5]. Countries such as Germany, the United Kingdom, the United States, and Japan have provided economic support to care robotics research [6-8]. Care robots are increasingly highlighted as an innovative way to provide geriatric care, and in a recent European Commission report, 20% of the most influential information technologies for aging projects included care robots [9,10]. Preliminary evidence suggests that care robots have the potential to improve the health of older adults, improve their general well-being and social interactions, and reduce their loneliness [11,12].

Despite these potential benefits, ethical concerns regarding the adoption of robots in aged care remain, including questions about autonomy, deception, and safety [5]. Barriers to the implementation of care robots include technical difficulties, limited capabilities, and negative perceptions [13]. With respect to caregivers, robots have both positive and negative effects on the work environment [14]. Together, these factors present a substantial headwind for both researchers and practitioners as they attempt to develop effective robotic interventions and understand related effects and best practices.

Nevertheless, the implementation of robots in care settings will have profound effects on health care delivery and work environments. As a result of the potential for these wide-ranging effects, several prior literature reviews have focused on care robotics. Existing reviews have examined in-home use of robots to promote aging in place [15-17], specific robotic applications (eg, telepresence robots) [18], relevant ethical issues [5], factors that affect the acceptability or implementation of care robots [13,19], and the impact of robots on caregivers [14]. We aimed to expand upon previous research by focusing our review within the context of assisted living facilities specifically. In addition, our review encompasses all types of robotic applications. Prior literature reviewing research on robots for older adults tends to focus specifically on social robots and on psychological or cognitive outcomes [20-24]. In comparison, our review encompasses a broader picture of robotic research, interventions, and outcomes relevant to caregivers and patients in this setting.

Instead of focusing on quality assessment and synthesis of a well-defined research question, scoping reviews map the current state of knowledge on a topic and identify gaps for future research [25-28]. This form of the review is thus appropriate to our broad research questions: (1) What is known about robots used in assisted living facilities? (2) What research methods, designs, and populations were used in this research? and (3) What gaps exist in the literature and warrant future research?

Methods

This study adhered to the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) protocol [29]. The PRISMA-ScR checklist is provided in Multimedia Appendix 1 [29].

Round 1: Keyword Search

As the subject under investigation was interdisciplinary—the use of robots in assisted living facilities—we searched databases in engineering, computer science, and health sciences: PubMed, CINAHL Plus with Full Text, PsycINFO, IEEE Xplore digital library, and ACM Digital Library. On February 12, 2022, we searched PubMed for titles and abstracts using the following sets of terms: (“robot*”) AND (“‘senior living facilit*’” OR “residential facilit*” OR “independent living” OR “assisted living” OR “‘senior living center*’” OR “nursing home*” OR “skilled nursing facilit*” OR “intermediate care facilit*”) AND (“aged” OR “older” OR “elderly”). These search terms were developed from the authors’ previous experience and by examining prior literature reviews in the field. To retrieve a full scope of the literature on our topic of interest, we imposed no time limit on years of publication. Then, we searched CINAHL Plus with Full Text and PsycINFO by titles and abstracts using the same sets of search terms. We then excluded duplicate publications using an electronic screening tool.

In addition, on February 12, 2022, we searched the IEEE Xplore digital library and ACM Digital Library (ACM Full-Text Collection) using the same sets of search terms. We searched IEEE by metadata (titles, abstracts, and indexing terms) and used the 2012 ACM Computing Classification System with the filter “Robotics” to search the ACM Digital Library. Duplicate publications were removed using an electronic screening tool. The publications identified from PubMed, CINAHL, and PsycINFO were combined with the publications from the ACM and IEEE databases, and additional duplicates were removed. A detailed search strategy for each database is provided in Multimedia Appendix 2.

Round 2: Screening of Titles and Abstracts

Next, the first author (KT) screened each of the nonduplicate papers by title and abstract using predetermined inclusion and exclusion criteria. The results were cross-examined by the other 3 authors, and disagreements were resolved through discussion. Inclusion criteria were as follows: (1) full text written in English and (2) focus on the use of robotics in assisted living facilities.
We used the National Library of Medicine’s Medical Subject Headings definition of robotics: “the application of electronic, computerized control systems to mechanical devices designed to perform human functions” [30]. Smart assistive devices (eg, walkers, canes, and transfer devices) and ambient assisted living technologies without a robotic platform were thus excluded from the review. Assisted living facility was defined as any residential setting that provides long-term care to older adults, consistent with prior literature reviews [11]. Studies on the in-home use of robots to promote aging in place were excluded. Projects that did not study the robot in a real-world setting were also excluded (eg, those that studied the robot in a laboratory environment or studied the infrastructure behind the robot). Publications were excluded if they (1) did not provide peer-reviewed empirical data (eg, literature reviews, opinion pieces, system architectures, and dissertations), (2) focused on user needs to guide future robot development, or (3) developed an instrument to study human-robot interaction.

Round 3: Screening of Full Text

The remaining papers were screened by full text using the same predetermined inclusion and exclusion criteria.

Round 4: Coding and Analysis of Full Text

Data from each of the papers in our final sample were then coded by publication year, study aim, research method, participants’ characteristics, sample size, country and setting where data collection took place, specific robot studied, outcome measures, length of study, and key findings. Two reviewers (KT and RT) completed the coding independently; disagreements were resolved through discussion.

Our data analysis, presentation, and discussion of results follow the PAGER (Patterns, Advances, Gaps, Evidence for practice, and Research recommendations) framework [28], identifying 5 key patterns in the reviewed literature, along with advances, gaps, evidence for practice, and research recommendations for each. Following the PAGER framework [28], the 5 patterns were identified through a patterning chart analysis of the study findings. The patterning chart displays key themes and how they are distributed across publications, which is then used to highlight important patterns and gaps in the included literature (Multimedia Appendix 3 [31-104]).

Results

Overview

In this section, we first describe the results of our search and screening process. We then report the key descriptive characteristics of the studies in our final sample. Finally, we describe the 5 key patterns identified from the findings of the final studies.

Search and Screening Results

During round 1, keyword search, our PubMed search yielded 108 publications. Our CINAHL search yielded 75 publications including 37 duplicates, and PsycINFO search yielded 75 publications including 31 duplicates. Excluding the 68 duplicates, 190 papers remained from the health sciences databases. For the engineering and computer science databases, IEEE Xplore digital library yielded 437 publications and ACM Digital Library yielded 58 publications. Two duplicates were removed from the ACM and IEEE databases, resulting in a total of 493 publications. Combining these with the 190 papers from PubMed, CINAHL, and PsycINFO revealed 4 additional duplicates, resulting in a total of 679 nonduplicate results.

During round 2, screening of titles and abstracts, a total of 552 publications were excluded (refer to Figure 1 for details), resulting in 127 publications.

During round 2, screening of full text, 54 papers were excluded (refer to Figure 1 for details), resulting in 73 publications.

Round 3, screening of full text, resulted in the exclusion of 54 papers. A total of 73 papers remained in the final sample. Figure 1 presents the full search and screening process [105].

https://aging.jmir.org/2023/1/e42652
Descriptive Results Based on the Coding of Full Text

The 73 publications included in our final sample reported 69 unique studies; 8 of the publications [31-38] reported on the same 4 studies. Key characteristics of the 73 publications are summarized in Multimedia Appendix 4 [31-104]. The publications were published between 2002 and 2022; >50% (41/73) were published in the last 6 years, suggesting a growing interest in our research topic. Furthermore, 3 studies were inspired by challenges related to the COVID-19 pandemic [39-41]. The studies were conducted in 17 countries—in Asia (22/69, 32%), North America (20/69, 29%), Europe (16/69, 23%), and Oceania (11/69, 16%). On the basis of the authors’ academic disciplines, 33% (23/69) of studies were identified as computer science or engineering oriented, 42% (29/69) were multidisciplinary, and the remaining were from health sciences (15/69, 22%) or social sciences (2/69, 3%).

The included studies were primarily designed to test the feasibility of a robot-based intervention. Feasibility studies assess whether an intervention is relevant and sustainable, and they can include limited efficacy testing [106]. Most of the studies (41/69, 59%) used quasi-experimental designs; the remaining studies were either case studies (21/69, 30%) or randomized controlled trials (7/69, 10%). Overall, 12 studies did not report the study duration; of those that did (57/69, 83%), the majority (37/57) lasted no longer than 6 months. Furthermore, 10 studies lasted <1 week, and 1 study [42] lasted 4 years. Only a few studies (6/69, 9%) [37,42-46] have reported the use of a theoretical or conceptual framework; the majority (63/69, 91%) lacked theoretical guidance. In addition, only a few studies (8/69, 12%) were user informed [47-51] or consulted clinical experts [33,52,53]; the remaining studies (61/69, 88%) lacked users’ or experts’ perspectives.

All studies used convenience samples, ranging from 3 older adults [31,54] or 3 recreational therapists [55] to 245 older adults in the largest study [38]. Five studies did not report the sample sizes [43,47,56-58]. Of the 66 studies that reported the sample sizes, 42 (66%) had no more than 25 participants. Most of the studies (48/64, 75%) collected data only from older adult recipients of care. Overall, 15 studies collected data on staff (eg, caregivers, therapists, board members, management, and preschool staff) [38,48,51,55-59,69], and 3 studies collected data on relatives or visitors [61,64,68]. One study [59], which examined the use of social robots for intergenerational activities, included 30 preschool children, and another study [70] used 6 young adults as a control group. The age of the older adult participants ranged from 55 to 104 years. Of the studies that reported demographic information, all but one [71] included >50% women participants. Of the 69 studies, 27 (39%) reported that they included older adults with cognitive impairments [31,41,42,45,52,53,69,70,72-90].

The studies examined a wide variety of robotic platforms and applications. The most commonly studied robot was PARO (n=22), followed by aibo (n=7) and NAO (n=7). Both PARO and aibo are pet-like robots, whereas NAO is a humanoid robot. The most common application of the robots was to provide social interaction or companionship to older adults (ie, social robots; 60/69, 87%). Less common uses were to assist caregivers with tasks related to their jobs (ie, assistive robots; 6/69, 9%) or to allow relatives and caregivers to provide remote presence to the older adults (ie, telepresence robots; 3/69, 4%).
Outcome measures, both objective and subjective, varied widely across studies. Observations, interviews, and surveys were the 3 most common methods of data collection. Observations were made by the research team, by caregivers employed at facilities, or via the robots’ software. Common observational measures included the number of interactions with robots, time spent interacting with robots, and emotional responses to robots. Observational measures collected by the robots included reaction time [31] and audio and facial tracking [88]. Three studies collected information on medication use [76,79,86]. More than 20 different questionnaires were used, but the most common were the validated and widely used Geriatric Depression Scale (n=4), the face scale mood evaluation (n=3), and the University of California Los Angeles Loneliness Scale (n=3). Furthermore, 4 studies collected physiological data, including blood pressure and heart rate [91], electroencephalogram [70], sleep-wake patterns obtained via wrist actigraphy [83], and salivary chromogranin [92]. Owing to the participants’ cognitive impairments, 3 studies [49,79,86] relied on proxy assessments of quality of life or pain.

Patterns of Research Findings
In addition to these key characteristics of the studies included in our final sample, we identified 5 key patterns of research findings.

Effects, Perceptions, and Experience of Care Robots
The overall findings were mixed; some studies suggested therapeutic effects of the robots, whereas others were neutral or inconclusive. The most commonly reported benefits of the social robots were improved mood and emotional states [33,41,42,44,49,52,55,72,74,76,78,80,81,84,85,92-94] and an increase in social interaction between the residents and other human interactors [31,36,41,42,52,55,58,59,63,69,72,75,81,82,95-98], including caregivers [69] and preschoolers [39]. Other commonly reported benefits of the robots were reduced loneliness [36,92,99], evoked positive memories of pets [59,65,85,96,100], improved quality of life [53,79] and well-being [65], reduced pain and pain medication use [85,86], cognitive stimulation [31,59,78], and improved behavior [49,55,80]. Several robots promoted movement [50,62,72,100,101], and 1 robot prevented unexpected falls [69]. Four studies [45,51,69,71] investigated robots that assist with medication administration, and in 1 study [69], the robot successfully prevented a medication error. Less frequently cited but objectively measured benefits included improved neuroactivity [70], reduced stress [92], decreased blood pressure [91], and improved sleep [83]. Several studies have investigated whether robotic pets could achieve the same benefits as traditional animal-assisted therapy. Three studies found that these robots were able to reduce loneliness [99] and stimulate interaction [75,82], with no differences between the robot and a live dog. One study [89] found that attention toward the robot decreased with time but remained stable with a live dog, whereas another study [35] found that the interaction was statistically significantly greater with the robot than with a live dog.

Residents and caregivers primarily reported positive experiences of using the robots and had positive attitudes toward the robots. However, a few studies [36,41,55,66,68,77,87,96] reported disapproval, and 3 studies [36,65,78] found that human companionship or human-facilitated interventions were preferred by the older adults. In 2 studies, the older adults perceived the robots to be dependent on them, which resulted in a sense of unwanted responsibility [41,96]. In 2 other studies, the older adults were not interested in interacting with the robots because they perceived the robots as toys [36,77]. In 1 study [66], the staff’s perception of the robots’ agency decreased over time.

Our review illuminated several concerns related to care robots as well as barriers to their use. Ethical concerns regarding privacy [54,64,69,95], maintaining autonomy [68,95], and age appropriateness of the robots [36,77] were common themes. One study illuminated safety concerns regarding relatives responding to emergencies via a telepresence robot instead of caregivers [64]. Barriers to use included technical difficulties [38,45,51,54,57,64,77,84,95], difficulty hearing [64,85,88,102] and seeing [48] the robots, and physical limitations [48,51,85,96,100]. However, other studies found the robots easy to use despite cognitive impairments and technological illiteracy [45,57,67,68,102].

Factors Influencing the Effects of Care Robots
Several factors have been repeatedly identified as possibly influencing the impact of care robots on older adults living in assisted living facilities. Gender was one such factor, although the results were inconsistent. For example, one study [102] found no differences between men and women participants, but another study found that robot interactions tended to follow socially constructed gender norms: men participants were primarily interested in the robot’s technical functions (“engineer-style” interaction), whereas women participants interacted with the robot as if it were alive [61]. The results were also mixed with respect to how participants’ age and level of cognitive decline affected robot-based interventions’ efficacy. Some studies found better results with younger participants [90] and those with milder cognitive decline [88,90], whereas others found better results with older participants [53] and those with more advanced cognitive decline [53,70,79,84]. Another potential factor that could have influenced the results of the studies was whether the robots spoke the participants’ native languages. In 3 studies, the robots did not speak the participants’ native language or use an appropriate accent, which may have contributed to reduced participation [66] and reduced satisfaction [34] as well as increased staff involvement for translation services [84].

In several studies, the robots’ limited capabilities reduced their efficacy or reduced the older adults’ interest in the robots [45,51,85,86,96,100,101]. For example, 1 robot’s [101] small size contributed to a reduced range of motion during physical therapy sessions. Another robot [45], which assisted older adults with medication administration, required caregiver presence because it lacked the essential capabilities for medication administration such as offering a glass of water. In 2 studies, the older adults wished that the robot had a companion element [51] or was more human like [100].

Novelty effects were a potential factor that may have affected the effects of care robots. Novelty effects are caused by the initial reaction to a new technology, as opposed to the effects
of long-term use once the technology is no longer perceived as new [103]. In 5 studies, the initial positive effects of the robots decreased or were no longer significant by the end of the study [80,84,86,89,91]. However, other studies have demonstrated that engagement with and benefits of the robots increased over time [38,42,44,60,62,98,104]. Although many of these studies were not long enough to refute novelty effects, 1 study [98] demonstrated an increase in interactions over a 7-week period; 1 study [62] demonstrated an increased willingness to interact with the robot over 8 weeks; 1 study [38] found that robot use increased from year 1 to year 2; and a 4-year-long study [42] demonstrated significant improvements in emotional, visual, and behavioral engagement from baseline.

**Robots’ Impact on Caregivers and the Care Environment**

Many studies (27/69, 39%) relied on facilitation of robots by researchers, nursing staff, or relatives [35,38,42-45,48,52,58,59,61,62,67,72,75-77,79-81,83,84,89,90,96,98,101]. Four of these studies [38,52,62,101] suggested one-on-one sessions or groups of <3 to maximize the benefits of robots, but one-on-one sessions were time intensive for caregivers [38]. Of the few studies that compared mediated and nonmediated interventions, 2 studies [43,59] found better results with less staff mediation, and 3 studies [61,72,96] found that the interventions were more effective with staff mediation.

Caregiver shortages have been repeatedly cited as a rationale for studying robots in assisted living facilities, but few studies have addressed the impact of robots on professional caregivers and their work environments. In studies that explored the impact of robots on professional caregivers, robot use was associated with nursing staff’s attitude toward the robot [65], caregivers’ high workload was identified as a barrier to incorporating the robots into care [65,96], and operating the robots was found to be a burden and increased workload for the staff [84,88]. One study [38] reported that caregivers desired more preprogrammed activities to reduce the workload associated with using a care robot, and another study [81] addressed this need by systematizing the use of a recreational robot, significantly increasing participation. Another study presented a system that allowed caregivers to teach a robot how to facilitate a game with residents and allowed caregivers to personalize the robot’s behavior [67]. Several studies emphasized that care robots were not meant to replace nurses, but instead they should be treated as an adjunct method of providing care [43,52,65]. One robot that played games with the residents freed caregivers to perform other tasks [33], caregivers in 1 study appreciated the help of a medication delivery robot [51], and another robot demonstrated the potential to reduce caregiver burden by responding to nurse calls and collecting real-time patient information [69]. The only study to compare job satisfaction before and after a robot intervention found a significant increase for the control group only, which received no robot intervention [66].

**Comparisons of Robot- and Human-Facilitated Interventions**

Instead of comparing robot-facilitated interventions with human-facilitated control groups, most studies (68/69, 99%) either had no control group or compared robot interventions with control groups that received treatment-as-usual. The studies that used treatment-as-usual control groups provided little to no description of usual care or how it was controlled for. This makes it impossible to determine whether the benefits discovered were because of the robot itself or because of the increased attention from being in a research study. Only 1 study in our review directly compared the effects of a robot-facilitated intervention with a comparable human-facilitated intervention [39]. The results of that study indicated that the therapeutic effects of occupational therapist–led sessions were significantly greater than those of robot-directed sessions. The authors concluded that robot-facilitated sessions cannot replace sessions with occupational therapists; however, they suggested that in settings with limited human resources, robots could be an appropriate alternative to occupational therapists [39].

**Methodological Approaches to Care Robotics in Assisted Living Facilities**

Several methodological limitations were noted throughout the final sample of studies included in our review. All studies in this literature review relied on convenience samples, and 5 studies lacked reporting on participant characteristics [43,47,56-58]. Observations, interviews, and surveys were the 3 most common methods of data collection. Observations were made by the research team, by caregivers employed at facilities, or via the robots’ software; however, little to no information was provided on how the assessors were trained. Finally, >20 different questionnaires were used, and there was little discussion about the reliability and validity of these measurement tools.

**Discussion**

**Overview**

This review examined 73 publications from 69 unique studies on the use of robots in assisted living facilities. The findings of studies on older adults were mixed, with some studies suggesting positive impacts of robots, some expressing concerns about robots and barriers to their use, and others being inconclusive. Although many therapeutic benefits of care robots were identified, methodological limitations weakened the internal and external validity of the findings of the studies. Few studies (18/69, 26%) considered the context of care: most studies (48/69, 70%) collected data only on recipients of care, 15 studies collected data on staff, and 3 studies collected data on relatives or visitors. Theory-driven, longitudinal, and large sample size study designs were rare. Across the authors’ disciplines, a lack of consistency in methodological quality and reporting makes it difficult to synthesize and assess research on care robotics.

Using the PAGER framework [28], we synthesized our findings into five patterns: (1) effects, perceptions, and experiences of care robots; (2) factors influencing the effects of care robots; (3) robots’ impact on caregivers and the care environment; (4) comparisons of robot- and human-facilitated interventions; and (5) methodological approaches to care robotics in assisted living facilities. Table 1 presents an overview of the analysis of these patterns. We discuss the implications of each in detail in the following sections.
Effects, Perceptions, and Experience of Care Robots

Various robotic platforms were presented in the reviewed studies; social robots were the most common (60/69, 87%), with PARO being the most frequently studied (22/69, 32%). Less commonly studied robots were assistive (6/69, 9%) and telepresence robots (3/69, 4%). The studies’ findings were mixed: some suggested therapeutic effects of the robots, but others were neutral or inconclusive. The most commonly reported benefit of the robots was improved mood and emotional states [33,41,42,44,49,52,55,72,74,76,78,80,81,84,85,87,92-94]. Other commonly identified benefits were increased social interaction [31,36,41,42,52,55,58,59,63,69,72,75,81,82,95-98], reduced loneliness [36,92,99], evocation of positive memories [59,65,85,96,100], cognitive stimulation [31,79,80], improved quality of life and well-being [53,65,79], reduced pain and medication use [85,86], improved behavior [49,55,80], and increased movement [50,62,72,100,101]. Similar findings were identified by other literature reviews [11,12]. In addition, there is some evidence that robotic pets could be a feasible alternative to animal-assisted therapy [35,75,82,99].

For the most part, participants accepted the robots and reported positive experiences of using the robots. The most common concerns related to the adoption of robots in the assisted living facilities were privacy [54,64,69,95], autonomy [68,95], age appropriateness of the robots [36,77], and safety [64]. Common barriers to use included technical difficulties [38,45,51,54,57,64,77,84,95], hearing and vision impairments [48,64,85,102], and physical limitations [48,51,85,96,100]. Similar concerns and barriers were noted in other literature reviews [5,13]. Although there is growing evidence of the potential for robots to improve the health of older adults, further research is needed to systematically explore the efficacy of care robots as well as participants’ perceptions and experiences of their use.

Factors Influencing the Effects of Care Robots

The impact of age and cognitive decline on the efficacy of care robots remains inconclusive. Some interventions appeared to be better suited for younger participants with milder cognitive decline [88,90], whereas others might be better suited for older participants with more advanced cognitive decline [53,70,79,84]. The impact of gender on the efficacy of care robots was also inconclusive (all but 1 study included in our review had a majority of women participants). The use of convenience samples makes it difficult to gain the perspectives of those who are resistant to care robots. Future studies should include study samples representative of assisted living facilities to fully

### Table 1. PAGER (Patterns, Advances, Gaps, Evidence for practice, and Research recommendations) framework.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Advances</th>
<th>Gaps</th>
<th>Evidence for practice</th>
<th>Research recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Effects, perceptions, and experience of care robots</td>
<td>Evidence shows mixed effects (positive, neutral, or inconclusive) and mostly positive perceptions and experiences of robots.</td>
<td>Further systematic research is needed to fully understand the effects, perceptions, and experiences of robot use.</td>
<td>There is growing evidence of the potential of robots to improve the health of older adults living in assisted living facilities.</td>
<td>Continue developing innovative robot models to meet the needs of older adults and caregivers. Collaborate with interdisciplinary teams to develop personalized robotic interventions, achieve representative samples, and explore novelty effects.</td>
</tr>
<tr>
<td>2. Factors influencing the effects of care robots</td>
<td>Evidence suggests that a user’s age, cognitive decline, gender, and culture impact the effect of robots.</td>
<td>Further study is needed to confirm and understand the factors that influence effects of care robots to inform personalization of robot interventions.</td>
<td>To develop effective robots, it is important to consider the factors that influence a person’s attitude and response to robots.</td>
<td>Study the impact of human mediation on the efficacy of robots. Study how robots impact caregivers. Involve caregivers directly in the design of robot interventions.</td>
</tr>
<tr>
<td>3. Robots’ impact on caregivers and the care environment</td>
<td>Evidence shows that human mediation affects the efficacy of robots. Evidence also shows that robots can increase workload for caregivers, which is a barrier to use.</td>
<td>Further study is needed on how human mediation affects robot efficacy. Evidence on how robots will be implemented into busy workloads is lacking.</td>
<td>It is crucial for caregivers to be considered in the design of robots.</td>
<td></td>
</tr>
<tr>
<td>4. Comparisons of robot-and human-facilitated interventions</td>
<td>Growing evidence supports the benefits of robot-facilitated interventions compared with treatment-as-usual, but when compared with equivalent human-facilitated interventions, the robot is less effective.</td>
<td>Research that compares robot-facilitated interventions and human-facilitated interventions is limited.</td>
<td>Growing evidence supports the benefits of robot-facilitated interventions, but there is little evidence that robots can provide the same quality of care as a human can.</td>
<td>Future research should carefully consider whether a robot-facilitated intervention is appropriate instead of a human-facilitated alternative. Future robot-based interventions should be designed to support human caregivers.</td>
</tr>
<tr>
<td>5. Methodological approaches to care robotics in assisted living facilities</td>
<td>A lack of consistency across disciplines in methodological quality and reporting makes it difficult to synthesize care robotics research and perform quality assessments.</td>
<td>Further systematic research is needed on the use of robots in assisted living facilities, with increased control and quality of reporting.</td>
<td>Methodological limitations reduce internal and external validity, making it difficult to make claims about the efficacy or best practices of care robots.</td>
<td>Develop interdisciplinary guidelines for conducting and reporting high-quality studies. Consult content experts to select appropriate and valid measurement tools. Use theory to guide studies.</td>
</tr>
</tbody>
</table>
understand the key factors that influence geriatric robotic care. Further research is also needed to examine whether and how novelty effects might affect residents’ and staff’s responses to care robots. Existing robots tend to have limited functions, which may have contributed to a novelty effect. Precart exposure to robots might be an effective way to reduce the impact of novelty effects [95].

These findings also suggest a need to personalize robot-based interventions rather than adopt a one-size-fits-all approach. The nursing discipline has a long tradition of valuing person-centered care [107]. Instead of standardizing care to a whole group of people, person-centered care is holistic, individualized to the unique needs of the person, respectful, and empowering [108]. With a person-centered approach, care robots will be more effective and will better meet the needs of older adults living in assisted living facilities. It is worth noting that 2 studies in this review attempted to personalize robot services, which evoked positive memories and engaged the older adults [34,42].

In addition to personalization based on age, level of cognitive decline, and gender, robots should be tailored to other important factors such as cultural backgrounds. This includes, but is not limited to, using the native language of users. A prior integrative review found that a person’s culture influences their attitudes, engagement, likeability, and perceptions toward a robot [109]. Further studies are required to understand the key factors that influence individuals’ attitudes and responses to care robots. The care robotics field will benefit from partnering with nurse researchers and others in the health sciences discipline who have experience in developing and implementing person-centered care.

Robots’ Impact on Caregivers and the Care Environment

Caregiver shortages have been repeatedly cited as a rationale for studying robots in assisted living facilities, but few studies have investigated the impact of robots on professional caregivers. Caregiver involvement was essential to the success of many robotic interventions, but few studies considered how robots would be implemented within an already heavy workload. Sharkey [110] argued that the benefits of robots are likely the result of skilled and careful use by caregivers and family members. Our findings support this claim and suggest that human mediation plays an important role in the efficacy of care robots; however, further research is needed to fully understand the impact of robot adoption and use on staff and family members. Knowing whether and how much human mediation is required to achieve the full benefits of care robots is essential because if the use of a robot is burdensome for caregivers, caregiver burnout will worsen or robots will not be used to their full potential.

The few studies in our review that focused on caregivers suggest that robots have the potential to increase the capacity for care by freeing caregivers to perform more meaningful tasks; however, robots also have the potential to increase workload, which is a barrier to their use. One study successfully increased participation by systematizing a robotic program to reduce barriers for caregivers [81]. It is crucial for researchers to carefully consider caregiver needs when designing robots; otherwise, the benefits identified in this literature review will not be achieved. Furthermore, future studies should address how robots will be implemented into an already busy workload.

Comparisons of Robot- and Human-Facilitated Interventions

Instead of comparing the robots with an equivalent human-facilitated control group, most of the studies (68/69, 99%) included in our review either had no control group or compared the robots with treatment-as-usual. Furthermore, these studies provided little to no description of usual care or how it was controlled for. This makes it impossible to determine whether the benefits discovered were because of the robot itself or because of the increased attention from being in a research study.

In a systematic review on the use of robot-assisted therapy for upper limb recovery after stroke, the authors emphasized that there is no reason to believe that robot-facilitated therapy would have better results than human-facilitated therapy if all other variables were the same [111]. The same is true for care robots in assisted living facilities, as evidenced by the studies that showed better results from human-facilitated interventions or preference for human-facilitated interventions [36,39,65,78,88]. Despite the limitations of using treatment-as-usual control groups, high-quality studies that compare robot-led interventions and usual care can be helpful for determining the benefits of care robots in comparison with the current state in assisted living facilities. With a growing gap between the number of older adults needing care and the number of professional caregivers, it might be unrealistic to expect assisted living facilities to implement additional human-facilitated interventions. Therefore, robots may be a more practical alternative. Either way, it is crucial to carefully consider whether a robot-facilitated intervention is appropriate instead of a human-facilitated intervention. More importantly, it may be necessary for researchers to recognize that robots should not fully replace humans and that robot-based interventions should be designed with the goal of supplementing humans.

Methodological Approaches to Care Robotics in Assisted Living Facilities

Although this review identified many reported benefits of using care robots, these findings should be interpreted with caution. The research practices and methods currently used in the development and evaluation of robotic systems fall short of those expected by the medical informatics and health technology research communities. Methodological limitations in studies on care robotics have been noted in several other scoping reviews [20-22,112,113]. Establishing standards in research design and in the reporting of study findings is urgently needed for this emerging interdisciplinary work, and it will increase the mutual contribution of caregivers and technologists as the field of robotics moves from the laboratory into its application in care settings. Many of the studies (15/69, 22%), especially those identified in the engineering databases, lacked reporting on methods and participants’ characteristics. This echoes a similar finding of a literature review that examined the use of artificial intelligence.
for caregivers of individuals with Alzheimer disease [114]. The lack of consistency across disciplines for what is considered high-quality research makes it difficult to synthesize care robotics research and perform quality assessments. As health care technology continues to advance and as disciplines further merge, it is increasingly important for interdisciplinary criteria to be established for studies and publications.

Observations, interviews, and questionnaires were the 3 most common methods of data collection in the reviewed studies; however, the specifics of these methods varied greatly among studies. More than 20 different questionnaires were used, which makes it difficult to compare the results of the studies, and few studies described the reliability and validity of their measurement tools adequately. Future researchers should consult content experts to ensure that appropriate and valid measurement tools are selected for the setting and population. Studies that relied on researchers’ or caregivers’ observations and assessments (ie, most of the studies) provided little to no information on how assessors were trained, which weakens the internal validity of the findings. Furthermore, serious concerns about bias arise from the widespread use of caregivers, who have prior relationships with residents, to observe and assess the residents. Although proxy measures are often appropriate and necessary for assessing participants with cognitive impairments and can sometimes be an efficient method of longitudinal data collection, no reliability assessments of these measures were conducted, and the studies did not supply information on the training of proxy raters.

The methodological limitations of the reviewed studies reduced their internal and external validity, making it difficult to make claims about clinical efficacy or best practices. To improve the level of evidence, attention should be given to developing interdisciplinary guidelines for conducting and reporting on high-quality studies as well as prioritizing theory-driven research. Although the methods used in these studies are commonly accepted for developing, demonstrating, and assessing novel robotic functionality, the responsible and successful application of robotic technology in care settings demands an evolution toward the standards of evidence and validity developed within health research broadly.

Limitations

Our scoping review had several limitations. First, it is possible that important and relevant studies were missed as only 5 electronic databases were searched. To mitigate this possibility, we chose a broad range of databases representing engineering, computer science, and health sciences. Second, we included only publications with full text written in English; therefore, it is possible that we missed important relevant studies written in other languages. Third, our search terms were not exhaustive, and we may have missed important relevant studies that used different terms for “assisted living facility” or “older adults.” To mitigate this possibility, we reviewed the search terms of prior literature reviews in the field and consulted an information science librarian. Fourth, owing to overlaps between robotic platforms and their uses, we did not further categorize the robots by type. Future work should focus on creating clear definitions of the different categories of care robots to facilitate clearer distinctions and comparisons.

Conclusions

The implementation of robots in assisted living facilities has profound implications for both older adults and professional caregivers. Care robots have the potential to improve the lives of older adults and the work lives of professional caregivers; however, concerns about their efficacy, ethics, and best practices remain. Despite the prevalence of research on this topic, relatively little work has been conducted with a specific focus on assisted living facilities and determining gaps in understanding how robots impact assisted living facilities. Previous research also overrepresents social robots relative to other types of assistive robots [115] and future research should ensure a more holistic approach going forward.

This scoping review identified 5 patterns of existing research (Table 1). Although existing knowledge, gaps, and recommendations for research vary across patterns, there are commonalities across them. Overall, we found a relative lack of systematic research methods commonly accepted in medical informatics to determine the feasibility and efficacy of robots in assisted living facilities. Research on how robots will change both geriatric care and the work environment of assisted living facilities is lacking, limiting our understanding of how robotics might impact the fuller context of care within which it will operate.

Interdisciplinary collaboration among health sciences, computer science, and engineering as well as agreement on methodological standards will be essential to enable care robotics research to realize its potential benefits and minimize its detriments to older adults and their caregivers. Although many approaches should be investigated, we suggest that formal categorizations of care work are a particularly promising artifact that can be used to strengthen the emerging collaborations that constitute care robotics for older adults and their caregivers.

A more holistic categorization of care interventions would provide a promising vantage point for the interdisciplinary negotiations needed to advance care robotics in a way that augments the skills and knowledge of care workers. The scope of care interventions provided by existing care robotics systems is very narrow, as evidenced in this study and elsewhere [116]. A more encompassing sense of what nurses and other care workers actually do could greatly inform the science of care robotics. Could nursing ontologies of interventions and outcomes help care robotics research be more accountable to care professionals and their patients? Could a sociological understanding of how nurses provide care inform the development of robotic technology designed to assist caregivers, rather than patients?

These questions and others must be fully explored so that robotic interventions can be appropriately oriented within the full context of care. Only by understanding patient needs and acknowledging existing care professionals’ knowledge and skills can robots assume a contributing role on care teams.
Acknowledgments
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Conflicts of Interest
None declared.

Multimedia Appendix 1
PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist.

Multimedia Appendix 2
Detailed search strategy.

Multimedia Appendix 3
Patterning chart analysis.

Multimedia Appendix 4
Summary of the 73 papers in the final sample.

References


4. Historic staffing shortages continue to force nursing homes to limit new admissions, creating bottlenecks at hospitals and reducing access to care for seniors. The American Health Care Association and National Center for Assisted Living. 2022 Jul 14. URL: https://tinyurl.com/44cuj8ea [accessed 2022-07-29]


Abbreviations

PAGER: Patterns, Advances, Gaps, Evidence for practice, and Research recommendations
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews

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Monitoring the Well-being of Older People by Energy Usage Patterns: Systematic Review of the Literature and Evidence Synthesis

Sophie A Korenhof¹, MD; Yuan Fang¹, PhD; Jie Luo¹, MSc; Tischa J M van der Cammen²,³, MD, PhD; Hein Raat¹, MD, PhD; Amy van Grieken¹, PhD

¹Department of Public Health, Erasmus University Medical Center, Rotterdam, Netherlands
²Section of Geriatrics, Department of Internal Medicine, Erasmus University Medical Center, Rotterdam, Netherlands
³Department Human-Centered Design, Faculty of Industrial Design Engineering, Delft University of Technology, Delft, Netherlands

Corresponding Author:
Amy van Grieken, PhD
Department of Public Health
Erasmus University Medical Center
Dr Molewaterplein 40
Rotterdam, 3015 GD
Netherlands
Phone: 31 107043498
Email: a.vangrieken@erasmusmc.nl

Abstract

Background: Due to the aging population, there is a need for monitoring well-being and safety while living independently. A low-intrusive monitoring system is based on a person’s use of energy or water.

Objective: The study's objective was to provide a systematic overview of studies that monitor the health and well-being of older people using energy (eg, electricity and gas) and water usage data and study the outcomes on health and well-being.

Methods: CENTRAL, Embase, MEDLINE (Ovid), Scopus, Web of Science, and Google Scholar were searched systematically from inception until November 8, 2021. The inclusion criteria were that the study had to be published in English, have full-text availability, target independent-living people aged 60 years and older from the general population, have an observational design, and assess the outcomes of a monitoring system based on energy (ie, electricity, gas, or water) usage on well-being and safety. The quality of the studies was assessed by the QualSyst systematic review tool.

Results: The search strategy identified 2920 articles. The majority of studies focused on the technical algorithms underlying energy usage data and related sensors. One study was included in this review. This study reported that the smart energy meter data monitoring system was considered unobtrusive and was well accepted by the older people and professionals involved. Energy usage in a household acted as a unique signature and therefore provided useful insight into well-being and safety. This study lacked statistical power due to the small number of participants and the low number of observed events. In addition, the quality of the study was rated as low.

Conclusions: This review identified only 1 study that evaluated the impact of an energy usage monitoring system on the well-being and safety of older people. The absence of reliable evidence impedes any definitive guidance or recommendations for practice. Because this emerging field has not yet been studied thoroughly, many questions remain open for further research. Future studies should focus on the further development of a monitoring system and the evaluation of the implementation and outcomes of these systems.

Trial Registration: PROSPERO CRD42022245713; https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=245713

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KEYWORDS

smart energy meter; healthy aging; activities of daily living; independent living; monitoring; older adults; devices; risk; well-being; effectiveness; design; safety

https://aging.jmir.org/2023/1/e41187

JMIR Aging 2023 | vol. 6 | e41187 | p.418 (page number not for citation purposes)
Introduction

The number of older people is increasing worldwide due to a global increase in life expectancy [1]. Between 2015 and 2050, the percentage of "older people," in this study defined as those 65 years and older, will nearly double as a proportion of the global population, from 12% to 22%, respectively [2]. As a result, the old-age dependency ratio (ie, the ratio of people aged 20-64 years to people 65 years and older) has declined from around 4 working adults for every person older than 65 years in 2001 to fewer than 3 in 2020 [3]. This means that roughly 1 adult older than 65 years is financially dependent on less than 3 working adults (aged 20-64 years) at present [4]. In addition, the proportion of single-person households in the European Union increased as well, from 25% in 2010 to 35% in 2017 [5]. Meanwhile, more and more older people live independently—the "aging in place" trend [6,7]. Independent living means noninstitutionalized living, with the possibility of extra professional help if needed [8].

Technologies are being developed within the health care sector to enable older people to live independently for longer. There is a wide variety of health technologies available to monitor symptoms of chronic disease; in the World Health Organization report on digital health, a complete overview is provided [9]. Technologies include the Internet of Things, virtual care, remote monitoring, artificial intelligence, big data analytics, blockchain, and smart wearables, but also platforms and tools enabling data exchange and storage and tools enabling remote data capture [9]. These technologies aim to provide the necessary tools to monitor the symptoms of chronic conditions like dementia. Research by Brownsell et al [10] showed that an individual's health status can be determined based on simple interactions between an individual and their immediate environment. This determination is the premise of activities of daily living (ADL) monitoring technologies, which aim to support the safety of the older person and enable both formal and informal caregivers to check in with the older person. For example, sensors are placed inside the homes of older people to detect movement, sleep patterns, occupancy, living conditions, or appliance usage [10]. There is a vast amount of literature available describing the potential of smart homes [10-12]. For example, a longitudinal study by Kaye et al [12] showed that the placement of infrared motion sensors could monitor walking speed and other in-home activity metrics. These solutions, however, require the installation and maintenance of specific hardware and software in the house or apartment of the older person. Additional sensors in the house or apartment, such as cameras, motion detectors, or heart rate monitors, can also be considered obtrusive, expensive, and violate the resident's privacy [11,13].

A potential low-intrusive system for monitoring may be designed using smart energy meter data. Smart energy meters are increasingly present in houses and apartments worldwide, automatically measuring and recording energy usage. A smart energy meter is a meter that keeps track of the energy supply and sends meter readings to the energy supplier automatically [14]. A study by Berg Insight [15] reported that the expectation is to reach 72% of smart electricity meter coverage in Europe by 2026. In 2024, in the EU, more than 100 million smart meters for electricity and over 50 million for gas will be rolled out [16]. This increase in coverage provides an opportunity for this type of research. The growing availability of smart energy meters and the relative simplicity of recording, storing, and transmitting data have created a potential opportunity to monitor activity among older people to support well-being and safety.

Specifically, age-related diseases, such as cognitive decline, have a direct impact on ADLs [17,18]. Based on the disaggregation of energy usage, ADL patterns can be established in a simple, unobtrusive, and inexpensive way [19]. By disaggregating the total energy load, it is possible to determine which appliances are being used on a certain day [20-23]. This technique, also known as nonintrusive load monitoring, makes it possible, by using algorithms, to infer the fine-grained energy usage patterns of different appliances in the household [20,24-26]. This energy usage pattern could be linked to health-related activities, such as cooking, which can therefore be used as a proxy for the general health and safety of the persons living in this household and possibly anticipate accidents or hospitalization [27].

The aim of this review was 2-fold. The first aim was to provide an overview of existing evidence describing initiatives that developed a monitoring system for the well-being and safety of independent-living older people using energy (ie, electricity and gas) and water usage data. For the remainder of the paper, we will use “energy” to refer to electricity, gas, and water. The second was to provide an overview of the outcomes of these systems on the well-being of older people. Moreover, if implementation outcomes were described, these were also reported.

Methods

Search Strategy

This systematic review was registered at PROSPERO (ID 245713). The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement was used as a guideline (Multimedia Appendix 1) [28]. A systematic literature search was conducted within the databases CENTRAL, Embase, MEDLINE (Ovid), Scopus, Web of Science, and Google Scholar in November 2021 to identify relevant studies. The following keywords were included in the search: “smart meter,” “energy meter,” “electric meter,” “gas meter,” “water meter,” “independent living,” “monitoring,” “support,” “activity recognize,” “anomaly,” “daily life activity,” and “community-dwelling.” The search strategy was determined in collaboration with a medical information specialist; the full search strategy can be found in Multimedia Appendix 2. Additional articles were added via a manual search for eligible articles based on the reference lists of the included articles.

Inclusion and Exclusion Criteria

Language

The inclusion criteria included studies published in English. Non-English studies were excluded from the study.
Article Availability

Only full articles were included. Conference abstracts and proceedings were excluded; for conference abstracts, corresponding authors were contacted for full text; these articles were excluded if they were unavailable.

Target Population

The study is based on independent-living people 60 years and older from the general population. Studies recruiting only clinical populations (eg, patients diagnosed with dementia) and studies among nonhumans were excluded.

Type of Study

Studies with an observational design (ie, a design where the participant is observed and analyzed in their natural or real-world setting) and that assessed the outcomes of a monitoring system based on energy usage on outcomes regarding the well-being and safety of the older people were included. Studies assessing only feasibility were excluded.

Study Focus

Studies that evaluated the monitoring system based on energy usage, including electricity, gas, or water were included. Studies using only wearable appliances to determine the well-being of the study participants (eg, heart rate appliances and movement sensors) were excluded.

Study Selection

All references were exported and managed using EndNote (version X9; Clarivate Analytics). After duplicate records were removed, title and abstract screening were performed independently by 2 reviewers (SK and YF), based on the predetermined inclusion and exclusion criteria described above. Relevant articles were retrieved for full-text reading and further review by 2 reviewers (SAK and YF). The 2 reviewers discussed disagreements until they agreed. The remaining disagreements were discussed with a third author (AvG) until a consensus was reached.

Data Extraction

A predetermined data extraction form was filled in with the extracted data from the included studies. Extracted information included the first author, year of publication, country, population and characteristics (ie, number of participants, type of population, and age of population), study design, study period, type of monitoring system, health-related outcomes, and effect size. This process was conducted by 2 researchers (SK and YF) independently. Discrepancies were resolved through discussion.

Quality Appraisal

The quality of the included study was assessed with the QualSyst (standard quality assessment criteria) systematic review tool of Kmet et al [29]. This checklist contains 10 items, which were scored from 0 points (no), 1 point (partial), to 2 points (yes). All scores were summed and consequently divided by the total possible sum score to calculate the quality score per study. With this final score, the quality of the study was then rated as high (≥0.75), medium (≥0.55 and < 0.75), or low (<0.55) [29]. This process was performed independently by 2 researchers (SAK and YF). Discrepancies between the researchers were discussed until a consensus was reached.

Results

Search Results

The search strategy identified 2920 articles in the selected databases. After deduplication, 1876 articles remained for the title and abstract screening. Based on the reference lists of the included articles and screened on title and abstract, 52 articles were added via a manual search for eligible articles. After title and abstract screening, 844 articles remained. After screening the remaining full-text articles for eligibility, 41 articles were eligible for inclusion in this systematic review. Finally, 1 article was included; in this article, 2 substudies were reported [27]. The PRISMA flow diagram is presented in Figure 1. The characteristics of the included study are described in Table 1.
Studied Characteristics and Results

We included 1 article that included the report of 2 substudies. In this study, Noury et al [27] aimed to develop a system for the remote monitoring of large populations of older people living independently at home. In addition, they developed an ADL index and evaluated the relevance and acceptability of the monitoring system as a whole. They used electricity data to study ADLs. They built a unique referential (ie, individual energy use pattern) for each subject, constructed from the mean energy usage of the selected ADLs: food preparation and eating, hygiene, and turning off appliances during diurnal and nocturnal periods. A unique ADL index was computed for each ADL and compared to the corresponding mean value in the referential.

The data was obtained by a detector on the residential power line to monitor the energy usage of each electrical appliance in a home [30]. This electricity usage monitoring system could memorize a “signature” for each appliance during a learning phase. Noury et al [27] referred to both ADLs and instrumental ADLs (IADLs). IADLs include housekeeping tasks such as “turning off appliances.” For the remainder of the paper, we will use ADLs to refer to both ADLs and IADLs [31].

The study consisted of 2 experiments, both conducted with older people living in single-person households [27]. The first experiment was conducted in 2005 with 13 participants from the LI2G lab (Laboratoire Interuniversitaire de Gérontologie de Grenoble) in Grenoble, France. The second experiment was

Table 1. Characteristics of the included study.

<table>
<thead>
<tr>
<th>First author (year of publication)</th>
<th>Country</th>
<th>Participants included, n</th>
<th>Study period</th>
<th>Type of study population</th>
<th>Study design</th>
<th>Age at participation (years)</th>
<th>Determinants or outcome</th>
<th>Level of quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noury et al [27] (2011)</td>
<td>France</td>
<td>13</td>
<td>Before 2008</td>
<td>Community-dwelling older citizens (1-person household)</td>
<td>Single-arm trial</td>
<td>80.5</td>
<td>Detection of ADL², validity of energy use (daily index of activity), acceptability of monitoring system</td>
<td>Low, b</td>
</tr>
</tbody>
</table>

ADL: activities of daily living.

Low quality as rated with the QualSyst systematic review tool by Kmet et al [29].
conducted with 12 participants, aged 80.5 (SD 3.2) years, in Sable-sur-Sarthe and Chatillon, France, in 2008. In this study, 3 ADLs (food preparation and eating, hygiene, and turning off appliances) in 4 time periods (morning, afternoon, evening, and night) were studied. Two additional activity levels (diurnal and nocturnal) were also studied, and an ADL index was built, which was validated by a social worker involved with the participants. The results of the study showed that electricity usage data could be a useful method to monitor independent-living older people’s ADLs. In addition, they tested this in 2 separate experiments in the population and showed that ADLs can be detected through electricity usage monitoring. They also showed that deviations from the normal 24-hour pattern could be linked to older people’s ADL patterns, which were subsequently linked with their health status and interpreted by a social worker. Furthermore, the study was well-accepted by both the participants and the social workers involved, and it was considered a little intrusive. However, participants were afraid of the costs involved in data transfer communications.

Quality Appraisal
The quality of the study, measured with the QualSyst systematic review tool of Kmet et al [29], was rated as low (<0.55). Overall, the QualSyst systematic review tool rated the quality of the evidence in this study as low, as it only included a small number of participants (n=25), and the objective, connection to the theory, data collection, data analysis, and outcomes were incompletely reported. Furthermore, no information on sampling strategy, verification, or reflexivity was reported. Moreover, the conclusion was only partially supported by the results. Next to that, participants self-reported their ADLs, and the questionnaires were not well described [27].

Discussion
Principal Findings
With this systematic review, we aimed to provide an overview of existing initiatives using energy data to monitor the well-being and safety of older people and to describe the outcomes of these energy data monitoring systems. Only 2 substudies were identified in the literature and reported in 1 article [27]. This 1 article was rated as low quality. Moreover, the outcomes for the well-being of older people were not visible. However, it did indicate that independent-living older people and social workers who participated in the study considered the energy usage monitoring system to be a little intrusive and a reliable and potentially beneficial solution for the time management of professionals involved in older persons’ care.

Implementation of Monitoring Energy Usage to Support Independent Living
Monitoring energy usage to support independent living requires a process of step-by-step evaluation and testing. It can be described as consisting of 3 elements: monitoring energy usage, appliance and activity recognition, and implementing the system in practice. Figure 2 illustrates the elements that are involved in studying the feasibility of energy usage monitoring.

First, regarding the ways of monitoring energy usage, there are 2 main ways of data collection: overall data from all appliances, via, for example, the smart energy meter, or data from just a single appliance. Both approaches have their advantages. Data from a single appliance does not need to be disaggregated; it is already known where the energy usage comes from. For data from the smart electricity meter, however, all electrical activity within the household is included, which requires disaggregation. The Noury et al [27] study described placing a detector on the residential power line, placed inside the main electrical supply cabinet, which monitored electricity usage and acted as a sensor for the total household consumption.

Second, regarding appliance and activity recognition, energy usage monitoring enables the identification of appliances through their energy usage patterns [17]. Subsequently, this pattern can then be used to identify ADL patterns. One way is appliance detection, whereby a pattern of a specific appliance can be recognized within the total energy usage; another way is historical ADL pattern recognition, whereby current energy usage is compared to historical energy usage [17]. Potentially, problems that have a rising prevalence with age, such as insomnia and possibly cognitive decline, can cause problems in ADLs [27]. Energy usage monitoring may, for example, detect deviations from the “normal” 24-hour pattern such as activity during the night [27].

The next step in appliance and activity recognition would be verifying the algorithms with real-life data. The studies identified in this review focused on testing algorithms mainly on already existing energy data or computer-generated energy data. These studies reported a reasonable (50%) to good (84%) accuracy for recognizing (kitchen) appliances [21,32-34].
Comparison to Prior Work

However, few studies were conducted to test the accuracy and outcomes of an energy usage monitoring system in real-life settings [17]. Billis et al [35] used smart television data to extract meaningful information about television usage patterns and subsequently associate them with the clinical findings of experts. Another study by Franco et al [36] tested the feasibility of a system for noninvasive monitoring of subjects at home by recording electrical activity from room lighting and other electrical domestic appliances. This type of monitoring—monitoring by specific types of appliances—is less sensitive to deviations from the average 24-hour energy usage pattern compared to an energy usage monitoring system operating via the smart meter because these particular appliances do not include the total activity of a household. However, the advantage of this system is that the collected data does not need to be disaggregated; it is immediately clear which appliance was used [35,36].

Lastly, it is needed to implement the system in practice and collect information on the impact on well-being, safety, and usability. The only article included in this review, by Noury et al [27], included energy usage monitoring, appliance and activity recognition, as well as testing the system in practice. Although the article of Noury et al [27] concluded that such a system is promising and appreciated by users, more research is needed to further confirm and elaborate on these findings. Moreover, to implement a monitoring system in practice, studies are needed to evaluate the design and usability of the system, for example, the client interface and communication.

Challenges to Implementing Energy Use Monitoring

Although energy usage monitoring is a promising method, some challenges should also be mentioned. We divided the challenges according to the levels of the socio-ecological framework [37]. First, on a personal level, energy usage monitoring is considered unobtrusive; however, privacy-related issues are still involved [32]. A study by Kolter and Johnson [32] reported that sharing real-time energy usage data can potentially be harmful since these data can easily be linked to being at home or not. During the rollout of smart energy meters on an international level, concern has been expressed within the population about the possibility of privacy breaches [38]. These discussions and issues should be considered in future studies evaluating the potential of smart-energy monitoring systems. Therefore, separating real-time energy usage data from identifiable personal data is essential. Furthermore, older people’s attitudes toward technology are relatively mixed [39]. Those who fear technology use are generally afraid of privacy breaches, loss of self-determination, and the replacement of human contact [39,40]. Others embrace technology and are more dependent on it, consequently more easily accepting possible negative side effects [39,40]. Counterintuitively, longer independent living can be supported by technologies and, therefore, might protect against a certain loss of privacy that will be in place when living in an institution [41].

Second, on a community and structural level, data collection from a smart energy meter can be easily achieved with a reliable internet connection, yet even in Europe, not everyone has access to the internet [42]. In addition, ADL patterns in older people are not always stable. It is relatively easy to detect deviations in ADL patterns; however, a deviation is not necessarily related to a change in health and could also mean that this person does not have a regular lifestyle [10]. Therefore, it can be challenging to relate deviations from normal ADL patterns to changes in well-being [10]. Discovering deviations in the lifestyle or ADL pattern would require longer-term monitoring. A potential advantage of monitoring electricity consumption by smart meters is that smart meters can perform this sort of long-term monitoring.

Strengths and Limitations

To the best of our knowledge, this is the first systematic review addressing ways to monitor the well-being and safety of older people using energy use data and describing their outcomes. Furthermore, we used a broad search strategy, including electricity, gas, and water, to identify all potential studies on this topic.

First, the main limitation of this systematic review is the lack of studies that could be included after screening—only 1. Overall, the QualSyst systematic review tool rated the quality of evidence in this study as low, as it only included a small number of participants (n=25), and the objective, connection to the theory, data collection, data analysis, and outcomes were incompletely reported. Furthermore, no information on sampling strategy, verification, or reflexivity was reported. Moreover,
the conclusion was only partially supported by the results. Next to that, participants self-reported their ADLs, and the questionnaires were not well-described [27]. The lack of studies might have induced selection bias. Second, another methodological consideration of this review is that publication bias cannot be ruled out as only peer-reviewed articles in the English language were included. Third, this review studied older people 60 years and older; there is no set age limit to define “older” [2,43]. In general, with age and decreasing mobility, the chances of unsafe situations increase. For example, adults older than 60 years endure the greatest number of fatal falls [44]. Nevertheless, implementing an energy-based monitoring system may also be useful for other subgroups, independent of age. If an age limit had been set, the conclusions of the review could have better suited a defined age group; now, they are better suited for various subgroups. Fourth, there are several ways, technically, to monitor energy data. However, in this review, we aimed to evaluate the impact of energy monitoring on the well-being and safety of independent-living older people. So, we have limited ourselves to the broad outlines of all technical energy activity monitoring possibilities.

Future Directions

The findings from this study indicate that energy usage monitoring may have the potential to aid in monitoring independent-living older people. Currently, the care for older people is organized more and more at home in Western countries [7]. Consequently, there will be relatively less capacity within high-need facilities for the rising numbers of older people [7].

First, further investigation of energy usage monitoring and the recognition of appliances and activities is required. Specifically, research is needed to examine whether, how, and for which subpopulations energy usage monitoring has potential. Heterogeneity between people increases with age, with an observed peak at 70 years; independent-living older people are therefore not a homogeneous group [45]. Furthermore, there are many levels of activity within a population, making it harder to build one system for the general population [46]. In line herewith, investigating the combination of electricity usage monitoring with other types of monitoring, such as via smart gas or water meters, could have great potential for increasing accuracy [47], especially as not all ADLs can be monitored by electricity usage, such as using the toilet or getting dressed. In addition, not all household appliances can be detected reliably yet [24]. Currently, smart electricity meters are the most installed; smart gas and water meters are less common but are also projected to increase shortly [15,48]. Household water usage can be disaggregated in various ways to produce similar data to electricity usage [49,50]. Smart water meters are at present mostly used for leakage detection and diminishing water use, but this information could also be used for ADL detection [51].

Second, it is recommended to implement the system in practice. Moreover, it is recommended that future studies apply a longitudinal study design with a larger sample size and longer study duration. Noury et al [27] included only 25 participants, who were followed up for 6 months. Since energy usage patterns are unique, it is important to include enough participants to have a representative sample of the target population [21]. Energy usage monitoring relies on energy pattern detection. Since energy usage is highly dependent on external factors like weather conditions, temperature, and the available appliances in a household, it is useful to follow a household for a longer period to take these factors into account and detect changes in 24-hour patterns.

Studies will also benefit from better measurement of well-being and safety outcomes. Since it is an emerging field, there have not been many scientific trials conducted in this field yet. The well-being and safety outcomes of energy usage monitoring and setting up a monitoring system based on this have not been well described yet. Noury et al [27] do mention health outcomes; however, it was not described which specific health outcomes were examined or how these health outcomes were measured. The other screened articles have not mentioned health outcomes at all.

Conclusions

In this systematic review, we aimed to provide an overview of existing evidence describing initiatives that developed and tested the outcomes of a system that monitors the well-being and safety of independent-living older people using energy usage data. Although only 1 article was included, which described 2 substudies that did not have sufficient power for definitive guidance for research and practice, this review has provided an overview of the current literature on energy usage monitoring systems for the well-being and safety of independent-living older people. The absence of reliable evidence impedes any definitive guidance or recommendations for practice. Future studies are recommended to further gain insight into both the technical development of a smart-energy usage monitoring system as well as the implementation of a system and its outcomes for older people and their caregivers.

Acknowledgments

We would like to thank Luca van Deursen for her assistance with the literature search. The study was designed by AvG and JL. SAK, YF, and JL analyzed and interpreted the data. SAK and YF drafted the manuscript; AvG supervised its writing. AvG, HR, and TJMvdC critically read and revised the manuscript. All authors have read and approved the final version of this manuscript.

Data Availability

Data sharing is not applicable to this study as no data sets were generated or analyzed during this study.
Conflicts of Interest
None declared.

Multimedia Appendix 1
PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement.
[PDF File (Adobe PDF File), 73 KB - aging_v6i1e41187_app1.pdf]

Multimedia Appendix 2
Full search strategy.
[PDF File (Adobe PDF File), 592 KB - aging_v6i1e41187_app2.pdf]

References
14. Smart meters make your bills more accurate. SSE Energy services. 2022. URL: https://sse.co.uk/smart-meters [accessed 2023-03-17]


30. Les produits sur-mesure nke WATTECO. Watteco. URL: https://www.watteco.fr/ [accessed 2023-03-17]


43. Older persons. UNHCR: The UN Refugee agency. 2018. URL: https://tinyurl.com/tau4s8w [accessed 2023-03-17]


Abbreviations

ADL: activities of daily living
IADL: instrumental activities of daily living
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QualSyst: standard quality assessment criteria

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Review

Domains, Feasibility, Effectiveness, Cost, and Acceptability of Telehealth in Aging Care: Scoping Review of Systematic Reviews

Yichi Zhang¹,², BSc; Jessie Siew-Pin Leuk¹, MSc; Wei-Peng Teo¹, PhD

¹Physical Education and Sports Science Academic Group, National Institute of Education, Nanyang Technological University, Singapore, Singapore
²Ageing Research Institute for Society and Education, Interdisciplinary Graduate Programme, Nanyang Technological University, Singapore, Singapore

Corresponding Author:
Wei-Peng Teo, PhD
Physical Education and Sports Science Academic Group
National Institute of Education
Nanyang Technological University
1 Nanyang Walk
Singapore, 637616
Singapore
Phone: 65 67903704
Email: weipeng.teo@nie.edu.sg

Abstract

Background: Aging is becoming a major global challenge. Compared with younger adults, the older population has greater health needs but faces inadequate access to appropriate, affordable, and high-quality health care. Telehealth can remove geographic and time boundaries, as well as enabling socially isolated and physically homebound people to access a wider range of care options. The impacts of different telehealth interventions in terms of their effectiveness, cost, and acceptability in aging care are still unclear.

Objective: This scoping review of systematic reviews aimed to provide an overview of the domains of telehealth implemented in aging care; synthesize evidence of telehealth’s feasibility, effectiveness, cost benefits, and acceptability in the context of aging care; identify gaps in the literature; and determine the priorities for future research.

Methods: Guided by the methodological framework of the Joanna Briggs Institute, we reviewed systematic reviews concerning all types of telehealth interventions involving direct communication between older users and health care providers. In total, 5 major electronic databases, PubMed, Embase (Ovid), Cochrane Library, CINAHL, and PsycINFO (EBSCO), were searched on September 16, 2021, and an updated search was performed on April 28, 2022, across the same databases as well as the first 10 pages of the Google search.

Results: A total of 29 systematic reviews, including 1 post hoc subanalysis of a previously published large Cochrane systematic review with meta-analysis, were included. Telehealth has been adopted in various domains in aging care, such as cardiovascular diseases, mental health, cognitive impairment, prefrailty and frailty, chronic diseases, and oral health, and it seems to be a promising, feasible, effective, cost-effective, and acceptable alternative to usual care in selected domains. However, it should be noted that the generalizability of the results might be limited, and further studies with larger sample sizes, more rigorous designs, adequate reporting, and more consistently defined outcomes and methodologies are needed. The factors affecting telehealth use among older adults have been categorized into individual, interpersonal, technological, system, and policy levels, which could help direct collaborative efforts toward improving the security, accessibility, and affordability of telehealth as well as better prepare the older population for digital inclusion.

Conclusions: Although telehealth remains in its infancy and there is a lack of high-quality studies to rigorously prove the feasibility, effectiveness, cost benefit, and acceptability of telehealth, mounting evidence has indicated that it could play a promising complementary role in the care of the aging population.

(JMIR Aging 2023;6:e40460) doi:10.2196/40460

KEYWORDS

telehealth; telemedicine; telecare; telemonitoring; aging care; health care access; scoping review; digital health; mobile health; mHealth; eHealth
**Introduction**

**Background**

According to the World Health Organization (WHO) statistics, there were 1 billion people aged ≥60 years in 2020, and this number is projected to reach 1.4 billion by 2030 and double to 2.1 billion by 2050 [1]. The shift in population demographics has substantially contributed to the rising demand for and cost of medical care [2], but many older people are still facing inadequate access to appropriate, affordable, and high-quality health care. In a 2010 survey across 32 countries in Africa, Asia, Eastern Europe, Western Europe, and the Caribbean, 63% of the 1265 respondents aged ≥60 years reported that access to health care when required was a challenge [3].

Telehealth, the delivery and facilitation of health and health-related services including medical care, provider and patient education, health information services, and self-care via telecommunications and digital communication technologies [4], is one of the many new possibilities that made health care more accessible and has been widely believed to bring various benefits in aging care settings. First, it can expand health services by removing geographic and time boundaries [5] and enabling socially isolated and physically homebound individuals access to a wider range of care options [6]. Second, it can minimize the risk of direct transmission of infectious agents from person to person [7], especially during the recent COVID-19 pandemic [8]. Third, it redefines health care by engaging the patients’ familiar settings, so that both the patients and the health care providers can put greater emphasis on the intervention itself, which in turn results in improved efficiency and quality of care [9]. Furthermore, as hospitals and medical providers are under increasing pressure to provide quality care at lower costs, telehealth has been accepted and successful across a variety of medical specialties and settings [9], such as dentistry [10], psychiatry [11], dermatology [12], and COVID-19 consultation [13].

The impacts of different telehealth interventions in terms of their effectiveness, cost, and acceptability were studied; however, the results were not consistent [14-16]. For instance, a systematic review of reviews by Ekeland et al [14] in 2010 showed that 21 of the 80 included reviews concluded the effectiveness of telemedicine, 18 found incomplete evidence, the remaining 41 reviews found limited and inconsistent evidence, and the costs of these interventions were not well understood. In 2021, Snoswell et al [16] revisited the meta-analyses from 2010 to 2019 and discovered that telehealth across a range of modalities could be clinically equivalent or more effective than usual care in cardiovascular disease, dermatology, endocrinology, psychology, nutrition, obstetrics, ophthalmology, psychiatry and psychology, pulmonary, and multidisciplinary care. In the same year, Goharinejad et al [15] conducted a review of systematic reviews in the field of telemedicine, in which the 191 included reviews covering different telehealth modalities (eg, telemedicine, telerehabilitation, tele-diabetes, telecardiology, home telecare, telepsychiatry, teledermatology, and teleneurology) and outcomes (eg, clinical outcomes, cost-effectiveness, and user satisfactions) revealed inconsistent evidence regarding the effectiveness (101 positive, 22 unclear, and 1 negative), cost benefits (42 positive and 20 unclear), and satisfaction (47 positive and 9 unclear). In view of the lack of synthesized evidence, particularly in aging care, and the increased demand for telehealth services since the COVID-19 pandemic [17], we would like to extend the literature by including the latest evidence and focusing on the applications of telehealth for the older population.

**Objective**

A scoping review generally aims to identify and map the evidence available on a certain topic [18-20]. It is an ideal tool for indicating the volume of literature available and provides a general or detailed overview of the topic’s focus [20]; identifying gaps in the research bases; and evaluating future research priorities in a formal, systematic, and transparent manner [21]. Considering the high heterogeneity of telehealth interventions, we sought to conduct this scoping review to identify the domains in which there is evidence for telehealth’s feasibility, effectiveness, cost benefits, and acceptability in the context of aging care; discover gaps in the literature; and determine the priorities for future research.

**Methods**

**Review Methodology**

This scoping review of systematic reviews was guided by the methodological framework of the Joanna Briggs Institute [22]. The study selection followed the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) flow diagram, and the reporting and mapping of the body of literature followed the PRISMA-ScR (Preferred Reporting Items for Systematic Review and Meta-Analyses extension for Scoping Reviews) guidelines [23]. The review protocol was registered in the Open Science Framework [24].

**Selection of the Reviews**

The eligibility criteria were established a priori [22]. We included different types of systematic reviews (eg, rapid reviews, narrative reviews, integrative reviews, systematic literature reviews, and systematic reviews with meta-analysis) that analyzed telehealth interventions involving older users or subgroup analysis of older users with or without known health conditions, including those residing in hospitals, nursing homes, and their homes. The intervention could be any form or subgroup analysis of telehealth intervention involving direct communication between older adults and health care providers. No restrictions were placed on the date and location of publications for this review. Only full-text reviews in English were included, considering the language proficiency of the reviewers, to ensure the quality of study selection and data extraction.

The systematic reviews were excluded if (1) the population did not consist of older adults or the reviews did not perform a subgroup analysis of older adults; (2) the reviews solely focused on the design or algorithm of telehealth interventions, policies, or experts’ opinions; (3) the reviews included a broader range of digital health or eHealth interventions but did not present a
subgroup analysis of telehealth interventions; (4) the language was not in English; or (5) full texts were not accessible.

**Search for Relevant Studies**

**Source of Studies**

In total, 5 electronic databases were searched to ensure comprehensiveness: PubMed, Embase (Ovid), Cochrane Library, CINAHL, and PsycINFO (EBSCO). Reference lists of the included systematic reviews were manually searched to identify potentially relevant reviews.

Haddaway et al [25] recommended Google Scholar search to identify gray literature in evidence reviews; however, Google Scholar is an “academic version of Google” [26] and only consists of a “scholarly” subset of the larger Google search index [27]. Therefore, we decided to use Google to identify any new relevant reviews, to ensure the completeness of the search. As Google’s search algorithm considers multiple factors and signals, we followed the procedure by Piasecki et al [28] and logged out of all Google accounts during the search to avoid personalized search results. Although we were unable to locate any more relevant results on the fifth and sixth pages, we continued browsing and stopped on the 10th page to ensure that there were no further relevant results.

**Search Strategy**

The search strategy for this scoping review used a 3-step search strategy. In the initial step, a limited search was undertaken in Embase (Ovid) for relevant systematic reviews, followed by an analysis of the index terms used to describe the articles and the text words contained in the title and abstract of retrieved papers. This step helped us identify two concepts for the search strategy: (1) aging and (2) telehealth. These two concepts and the choice of databases were discussed and agreed upon in consultation with an experienced librarian (YLM) and all team members. In the second step, all identified keywords and index terms were used to develop our final search strategy, which had been consulted with the librarian (YLM) and compared with the published literature to ensure comprehensiveness. As a result of the preliminary search, some of the possible relevant systematic reviews identified did not include the term “review” in their titles or abstracts; therefore, adding the third concept “review” might result in such reviews being excluded. The detailed search strategy and results across all the included databases are provided in Multimedia Appendix 1. Finally, the reference lists of all identified systematic reviews in the included full texts were searched for additional articles.

**Selection of Studies**

The study selection consisted of two levels of screenings: (1) title and abstract screening and (2) full-text screening, and the reasons for all excluded full texts were recorded. In the first level of screening, 2 independent reviewers (YZ and JSPL) first screened the titles and abstracts of a random sample of 10% (620/6198) of the retrieved articles to ensure consistency in the interpretation of the inclusion and exclusion criteria, while discussions were conducted to reach a consensus in case of any discrepancies. Subsequently, they independently screened the remaining articles, and any study with unclear eligibility was conservatively included in the next step of the full-text screening. Only accessible full-text reviews were considered, and all attempts were made to access full-text copies of the selected articles, with the help of the librarian (YLM) or by directly contacting the author via email.

In the second step, 2 reviewers (YZ and JSPL) independently assessed the full-text articles of all selected reviews. When discrepancies in the assessment were encountered, reviewers discussed among themselves, or with a third reviewer (WPT) acting as a mediator, to achieve consensus.

**Data Charting**

YZ extracted the characteristics of the included systematic reviews using a data charting form, which included the following items: article title, country of the authors, publication year, type of review (with a reason for not conducting a meta-analysis, if applicable), review aim, number of articles included, conceptual and operational definitions of the terms related to telehealth, inclusion and exclusion criteria, outcomes with main findings, quality of evidence, limitation of the reviews, and future practice and research recommendations. Data were manually copied and pasted wherever possible to avoid any potential misinterpretation.

**Results**

**Search Results**

Figure 1 illustrates the preferred reporting items for the PRISMA flowchart of the study selection process. The initial database search conducted on September 16, 2021, identified 9700 articles, and 6198 (63.9%) were included in the title and abstract screening stage after 3502 (36.1%) duplicates were removed. In the full-text screening, 1257 articles were assessed for eligibility, and 17 systematic reviews were found to be relevant, including 1 post hoc subanalysis of a previously published large Cochrane systematic review with meta-analysis [29]. We performed another updated search on April 28, 2022, in the same databases as well as the first 10 pages of the Google search and identified another 12 relevant systematic reviews. As a result, 29 systematic reviews were included for data extraction in this scoping review.
Characteristics of the Included Systematic Reviews

The characteristics of the included studies are summarized in Multimedia Appendix 2 [30-61].

Of the 29 reviews, 2 (7%) were published before 2010 [62,63], 15 (52%) were published between 2010 and 2019 [29,64-77], and 12 (41%) were published between 2020 and April 2022 [78-89]. A total of 19 reviews provided details on the locations of the included studies [63,68-78,80,81,83,84,86,88,89], with the most prevalent being in North America (the United States and Canada) [63,68-77,80,83,86,88,89], Europe (the United Kingdom, France, Italy, Sweden, the Netherlands, etc) [63,68-71,73-78,80,83,86,88,89], and Australia [68-71,77,78,80,81,86].

The majority of the reviews were narrative, except for 4 that included a meta-analysis [65,74,84,86]. Among the remaining 25 narrative reviews, 5 explained that a meta-analysis was not carried out given the heterogeneity of design, participants, and intervention types [63]; data reporting with the variability of methodology in the studies [67,81]; low quality of the included articles [68]; and high selection and publication bias [78].

A total of 24 reviews presented either a conceptual definition (a working definition in terms of its abstract concept [90,91]) or an operational definition (specific process, events, or activities that the researcher used in the measurement to determine the concept [92]) of at least 1 of the 15 terminologies used (ie, telehealth, telemedicine, telecare, structured telephone, telepsychiatry, remote patient monitoring, teledentistry, telemonitoring, health information technology, remote care programs, telephone only support, remote activity monitoring, telenursing, decision support systems, and health coaching systems), and a summary table can be found in Multimedia Appendix 3.
Domains of Telehealth Use in Aging Care

Population of Interest

Of the 29 included reviews, the population of interest comprised older patients with at least 1 health condition in 17 (59%) reviews [29,62-64,66-69,71-74,78,80,82-84]. Among all these health conditions, the most prevalent ones are cognitive impairment (eg, dementia [82,83] and mild cognitive impairment and Alzheimer disease [66,69]), heart failure [29,80], and frailty or frailty [63,74], followed by leg and foot ulcers [72], chronic obstructive pulmonary disease [64], unipolar depression [68], hypertension [84], and oral health [78].

The remaining 12 reviews targeted the general older population, regardless of health conditions. Ten reviews set age cut-offs of 50 [77,79], 55 [87], 60 [70,75,86,89], and 65 years [65,85,88]. Three reviews focused on telehealth services during the COVID-19 pandemic [81,83,88].

It was also reported in several reviews that older adults were not able to participate in telehealth research because of the following factors: sensory change (eg, visual or auditory impairment) [70,82,83], negative affect [83], cognitive impairment [68,70,74,75,82], and communication barriers [70,82].

Interventions of Interest

The most prevalent modalities of telehealth interventions in the included reviews focused on remote consultation via mobile phones or video calls [29,64,65,67-69,72,76,77,81], remote monitoring or telemonitoring with synchronous or asynchronous data transmission [64,70-72,85], home-based telecare services [63,66,73,75], and nurse-led telecare services [62,66]. Tam et al [84] examined text messaging in hypertension management; Markert et al [85] investigated remote monitoring combined with health coaching; and the other reviews did not differentiate the different telehealth modalities, with aims including, but not limited to, screening, diagnosis, support, consultation, and education.

According to WHO, universal health coverage is the idea that everyone can access a full range of essential and quality health services, including promotive, preventive, curative, rehabilitative, and palliative care [93]. Most included reviews focused on curative and rehabilitative care (28/29, 97%), and health education interventions were excluded from 3 reviews [29,64,67].

The detailed inclusion (population, intervention, and comparator) and exclusion criteria of the 29 reviews can be found in Multimedia Appendix 4.

Outcomes With Findings

Outcomes of interest in this review included the effectiveness in individual outcomes (clinical benefits, health literacy, and behavioral outcomes) and system outcomes (efficacy and impact on health system use), feasibility and cost benefits of telehealth interventions or programs, and older people’s acceptance of telehealth with factors affecting their telehealth use.

Effectiveness of Telehealth

Individual Outcomes: Clinical Benefits

In total, 17 reviews have documented the clinical benefits of telehealth interventions for older adults, in which a clinical benefit is defined as “a favorable effect on a meaningful aspect of how a patient feels (e.g., symptom relief), functions (e.g., improved mobility) or survives as a result of treatment” [94]. In the included reviews, such outcomes included self-reported or clinically assessed health outcomes [62,63,65,66,68-70,72,74,77-79,84,86,87], hospitalization rate [29,81], the mortality rate [29,85], and quality of life [65,77,79,86].

All these reviews have suggested a promising impact of telehealth interventions on the clinical benefits for older adults. Post hoc analysis of a previously published systematic review with meta-analysis by Inglis et al [29] showed that remotely monitoring older patients with heart failure using structured telephone support or telemonitoring could reduce mortality rates and all-cause hospitalization. Likewise, Tam et al [84] performed a meta-analysis to assess the effectiveness of text messaging interventions in hypertension management and concluded that text messaging could substantially reduce systolic blood pressure in older adults. However, there is a lack of rigorous evidence to further support the clinical benefits of these telehealth interventions.

Individual Outcomes: Health Literacy

Two reviews reported an improvement in older adults’ health literacy, which is “the achievement of a level of knowledge, personal skills and confidence to take action to improve personal and community health by changing personal lifestyles and living conditions” [95]. Santana et al [66] reported a better understanding of the basic pathology and comorbidities among older adults with Alzheimer disease and an improvement in older adults’ behavior management skills via the use of telecare. Similarly, according to Constanzo et al [69], all included studies concluded that participants with cognitive deficits were able to relearn everyday skills by using different technological tools, particularly when learning methods with error reduction were used.

Individual Outcomes: Behavioral Outcomes

The effects of telehealth interventions on various behavioral outcomes of older adults were studied in 3 reviews. van den Berg et al [70] found that regular personal monitoring and individual support by a health care provider or in the form of telemedical measurements seemed to have a positive influence on the adherence to behavioral changes (eg, adherence to medication, diet, physical activity, daily life activities, self-efficacy, and disease management compared with the other outcome categories). Tam et al [84] found a moderate effect on improving medication adherence by integrating telemedicine interventions. Finally, Rush et al [87] presented the use of telehealth as a possible solution to modify older adults’ unhealthy behaviors (eg, smoking) that are higher in rural and remote areas than in urban areas.
System Outcomes: Efficacy of the Telehealth Intervention or System
In total, 8 reviews explored the efficacy of telehealth interventions and reached inconsistent conclusions. Jones and Brennan [62], Barlow et al [63], Gentry et al [77], and Markert et al [85] found some evidence of the efficacy of telehealth interventions, although more rigorous evidence is needed. In contrast, Marx et al [65] and Costanzo et al [69] did not find a difference between telemedicine and in-person diagnosis and home visits, and Sekhon et al [82] found inconsistent results on the reliability of telemedicine caused by the testing conditions and the accessibility of telemedicine. In addition, Markert et al [85] reported that the presence of humans in the interventions might influence the outcomes. Jones and Brennan [62] revealed that the use of telehealth for clinical assessment has shown great promise in the nursing process; however, it was not ready for wide-scale clinical deployment.

System Outcomes: Impact of Telehealth on the Health Care System Infrastructure
In total, 7 reviews included the impact of telehealth on health care system use as an outcome. Barlow et al [63] showed that telephone follow-ups after hospital discharge were associated with reduced health service use (e.g., lower hospital admissions and costs), Franek [64] reported that home telemonitoring could reduce the use of other health care services with a need of further confirmation with more randomized controlled trials (RCTs) of high quality, and Murphy et al [81] demonstrated that a telemedicine-based geriatric clinic model of care had the potential to reduce acute hospitalization and shorten the waiting times. The other 4 reviews demonstrated the potential benefits of telehealth services in improving older adults’ access to health care [68,83,88] and extending existing health services from the health care facilities to home and community [86].

A summary of the effectiveness outcomes and findings can be found in Multimedia Appendix 5.

Feasibility of Telehealth
To measure the feasibility of telehealth, earlier studies used different indicators, such as use [96], adherence [97], dropout rates [98], technical errors [98], specialist consultation time [98], perceived feasibility [99], delivery mode [100], and social accountability [100]. Considering the lack of details in the included reviews, we opted to use adherence and attrition rates as proxy measures.

Three reviews reported on older users’ adherence to telehealth interventions. In the review by Sekhon et al [82], mixed results were reported on the actual rate of adherence to telehealth and the implementation of telemedicine specialists’ recommendations. In addition, Rush et al [87] also indicated that half of the studies reported low adherence and modest attrition rates because of technology failure and not achieving behavioral goals, and the adherence rates were found to vary according to the nature of telehealth interventions. Santana et al [66] reported an improvement in adherence to treatment, an increase in the number of older adults accompanied by health providers, and an improvement in the quality of care. The review with meta-analysis by Marx et al [65] found that more than half of the studies (7/9, 78%) found a much lower attrition rate among those who used telephone consultations (0%-31%) than those who used telemonitoring devices (50%-61%). A summary of the feasibility outcomes and findings can be found in Multimedia Appendix 6.

Cost Benefits
In total, 6 reviews examined the cost benefits of the telehealth interventions. Marx et al [65] concluded that telehealth interventions were cost-effective compared with no intervention, but the cost-efficacy compared with home visits was not yet established. Peretz et al [73] found no reliable cost estimates for remote patient monitoring program implementation, but it appeared that the cost of remote patient monitoring programs was dependent on the number of vital signs monitored, the complexity of the health condition monitored, and the geographic locations of the programs. Among the studies included in the review by Gentry et al [77], only 1 found no health care cost difference between virtual consultation and in-person treatment, whereas the other studies on memory disorder clinics via telemedicine only supported cost benefits to patients and caregivers but found no evidence of cost-effectiveness for health care organizations. In dentistry, Aquilani et al [78] found that telehealth interventions tended to be less costly than face-to-face oral examinations. In the review by Murphy et al [81], virtual geriatric clinics were likely to be more cost-effective, but substantial discrepancies were noted in 2 studies because they used different costing models. The review by Rush et al [87] included studies of medium to high quality and observed direct cost savings for the health care system and rural older adults; however, many of the cost savings resulted from the savings on travel expenses. A summary of the cost-benefit outcomes and findings can be found in Multimedia Appendix 7.

Acceptance of Telehealth
A summary of the acceptance outcomes and findings can be found in Multimedia Appendix 8.

Satisfaction, Acceptability, Attitude, Experience, and Usability
In total, 12 reviews reported users’ attitudes, satisfaction, or acceptance of telehealth services. Narasimha et al [76] reported that 65% of the geriatric population has shown a strong will to keep abreast of current advances, despite the stereotype that older people may be more averse to using technology for health care. Positive attitude toward telehealth was also reported in other reviews [62,66-68,77,78,81-83]. If the attrition rate could be used as a proxy for older users’ acceptance, Marx et al [65] found that among the geriatric population, acceptability was good for telehealth consultation but less desirable for asynchronous approaches that relied on computerized devices. Moreover, Costanzo et al [69] discovered that younger caregivers seemed more comfortable and capable of using the internet and were more motivated to use the service.

Factors Affecting Older Adults’ Use of Telehealth: Overview
In the 1970s, Urie Bronfenbrenner developed the social ecological model as a conceptual model to understand human development. It consists of nested circles centered at individuals.
and contains microsystem, mesosystem, exosystem, macrosystem, and chronosystem levels [101]. In this review, we adapted the social ecological model as a framework to guide the classification of the factors affecting older adults’ telehealth use, namely, individual, interpersonal, technological, system, and policy levels (Figure 2 [101]).

Figure 2. Illustration of our model, which was adapted from the social ecological model [101]. UI: user interface.

Factors Affecting Older Adults’ Use of Telehealth: Individual Level
At the individual level, aging-related declines in vision, perception, hearing, motor, and cognitive functions adversely affected older adults’ ability to carry out tasks, thus increasing the challenge of telehealth use and the inaccuracy of assessment [67,68,76,77,79]. For older adults who are unfamiliar with technologies, telehealth may bring technical difficulties and cultural challenges [71,83], and some even dropped out of the studies [70]. Such factors may lead to resistance to technology use [68].

Factors Affecting Older Adults’ Use of Telehealth: Interpersonal Level
Some health care providers reported difficulty in communicating and conducting proper physical examinations via telehealth owing to older patients’ possible age-related declines and technological incapability [67,68,83]; therefore, they were reluctant to recommend technologies. Moreover, it was recommended that more communication between patients and staff as well as between peers could create a feeling of more involved care [80].

Factors Affecting Older Adults’ Use of Telehealth: Technological Level
At the technological level, both hardware and software factors have been reported to affect telehealth use in the older population.

Regarding hardware factors, ownership of technology [79], an effective device or display screen [71,76], bandwidth, and connectivity [77,83], along with a need for devices with widgets or multiple screens [71], could influence older users’ ability to accomplish the final goal. For example, some patients with hearing disabilities reported interference between a videophone and their hearing aids [76]. The convenience of technology use can improve comfort and efficiency.

Regarding software factors, several reviews identified barriers in terms of the software and user interface design, such as inappropriate font size, unusual characters, bland graphics, poor color contrast, and complicated menu designs [76,79]. A simple and intuitive interface that requires little or no technical knowledge would better reflect normal daily activities and allow a more seamless transition toward its use [80], whereas a delay in responses, lack of feedback, and technical issues may lead to frustration for older users, which may lower their motivation to continue telehealth use [71].

Factors Affecting Older Adults’ Use of Telehealth: System Level
An important factor regarding older adults’ telehealth use is access, which may be limited by age-related sensory impairment [67,68] and unfamiliarity with technology [68], as reported at the interpersonal level. Sekhon et al [82] also reported that gaining a referral to a specialist who uses telemedicine was another barrier, although all physicians claimed future use of telehealth. In addition, skepticism about the telehealth benefits [68] and information loss owing to the inability to properly examine patients [83] were other 2 barriers reported by health care providers.

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Factors Affecting Older Adults’ Use of Telehealth: Policy Level

At the policy level, several reviews reported that the cost of using telehealth and reimbursement from the government or insurance companies were barriers to telehealth adoption [77,79]. Other barriers reported at the policy level are regulations (eg, state law and licensure) as well as ethical and legal issues (liability, malpractice, and safety) [77,89].

Data privacy was a contradictory factor in these reviews. In the review by Karlson et al [75], possible privacy issues caused by the use of cameras and video recording tools were not seen as a problem by most older adults because the technologies were supposed to help them live safely in their own homes. In contrast, the reviews by Pool et al [89] and Kruse et al [79] reported that the privacy issue had an impact on user attitudes, intentions to adopt, and their actual use of telehealth.

Quality of the Evidence Included in the Reviews and Limitations of the Reviews

Most of the included reviews reported that the literature did not meet orthodox quality standards because of the study design in the lower tiers of the hierarchy of evidence [63,69,71,72,79,81]; small sample size [63,65,68,69,71,82,86]; short follow-up period [63]; small number of studies [63,65,66,68,79,81,84]; high risk of bias [67,71,72,74,84]; high heterogeneity of interventions and outcomes [64,67,69,78,81,86,87]; insufficient and partly inadequate reporting of predefined outcome values and few participants, especially in the intervention group [72]; and inconsistent measurement of the outcomes [67,69,87]. The included studies of all the reviews were conducted in a limited number of locations (Multimedia Appendix 2), and the interventions used different telehealth modalities in different settings; hence, generalizability was attenuated [64,68,75,81], and the findings might not be generalizable to the entire older population group.

Discussion

Principal Findings

This scoping review synthesized the evidence from past research on telehealth in aging care and summarized the findings of 29 systematic reviews regarding telehealth interventions in aging care. Although telehealth has garnered attention since before 2010, it was in the spotlight during the COVID-19 pandemic when >40% of the included reviews were published. The present evidence shows promising evidence regarding the feasibility, costs, and acceptability of telehealth for screening, diagnosing, supporting, and consulting in aging care. However, some discrepancies were observed because of differences in telehealth modalities, health conditions, definitions of outcomes and measurements, and costing models. In addition, we summarized and categorized various factors affecting older people’s telehealth use into individual, interpersonal, technological, system, and policy levels to provide a pathway for collaborative efforts to better prepare the older population for digital inclusion.

A large proportion of the evidence focused on curative and rehabilitative care (28/29, 97%), and there is scarce evidence on promotive, preventive, and palliative care, which is consistent with the scoping review in 2013 that the largest number of studies primarily focused on chronic disease management and symptom management [102]. Despite the importance of health education and promotion for the whole population, older adults have long been left out of health promotion activities until after 2001 when WHO experts declared that a healthy lifestyle should be emphasized for all ages [103]. Evidence has indicated that a healthy lifestyle, such as quitting smoking, limiting alcohol consumption, and increasing physical exercise, can help delay the development of many diseases, prevent the loss of functional capacity, improve the quality of life, and extend life expectancy [103]. Palliative care is another important public health issue as a consequence of the aging population, which focuses on improving the quality of life and dignity of people facing the end of their lives as well as the support and care of their loved ones [104]. For most patients in need of palliative care, the most preferred place of care is at home [105]. Nevertheless, some unmet in-home palliative care needs, such as the lack of communication among health care providers and patients’ uncertainty about the urgency of their problem, have also been reported [106]. Future research could investigate how telehealth can address these gaps and the role of telehealth in universal health coverage.

In comparison with usual care, different modalities of telehealth have demonstrated remarkably promising effectiveness in improving both individual outcomes and system outcomes. As Russell et al [107] stressed that it is important to ensure that telehealth is not inferior to usual care, our results support past reviews [14-16] that telehealth could be a viable alternative to traditional clinical practice in selected domains and further highlight that telehealth could be effectively used in a broad range of clinical disciplines. However, we should be cautious about possible biases in the literature that may limit the generalizability of the results. For instance, most empirical studies in the included reviews were conducted in countries with higher incomes, and older adults with chronic or aging-related conditions were excluded in some studies if they were not part of the target population. Moreover, our findings also reiterate the inconsistent quality of evidence reported in other reviews [14,108]. The included reviews were predominantly narrative (25/29, 86%), and most reported that the literature was not up to orthodox standards. The evidence base needs to be strengthened through additional studies on the top tiers of the hierarchy of evidence (eg, RCTs or cluster RCTs) with larger sample sizes, longer follow-up periods, and consistent definitions and outcome measures coupled with good reporting methodologies.

In terms of the feasibility of telehealth in aging care, we used users’ adherence and attrition as proxy measures and found mixed results, varying by different telehealth modalities and subpopulation types. Indeed, suboptimal adherence and substantial attrition are common in digital health intervention studies among the older population [109,110], and some contributing factors include personal choices, technical difficulties, physical and cognitive impairments, and concerns regarding the security of digital health interventions [110]. Low engagement continues to plague the internet-based studies [111], results in a study cohort not being representative of the
demographics and disease status of the originally recruited study population [109], thereby threatening the validity of the findings [112]. Meanwhile, other factors such as referral by a clinician to the study, compensation for participation, having a clinical condition of interest in the study, and an older age [109] have been revealed to be associated with increased participation retention. Future research could further explore how older users’ adherence and retention rates could be improved to advance the current telehealth practices and how this could impact the effectiveness, costs, and acceptability of telehealth interventions.

Similar to the systematic review of reviews by Ekeland et al [14], several reviews in our study also reported promising benefits of telehealth in terms of cost, and we also observed some discrepancies in implementation cost savings and cost-effectiveness in different studies owing to heterogeneity in comparator care delivery modes [65], the complexity of health conditions [73], geographic locations [73], and cost models used [77,81]. A common obstacle in most published economic evaluations of digital health interventions is reliance on standard methodological recommendations for assessing health care technologies, but such methodological assumptions may not fully reflect the nature of digital health interventions, especially complex ones [113]. Moreover, the cost benefits of digital health interventions may vary over time as well as the degree to which users use them, making their impact more likely to be heterogeneous [113-115]. Further research could overcome these challenges by streamlining the methodologies. For example, as recommended by Gomes et al [113], researchers should carefully choose comparators, determine the scope of cost and effects to be considered, and identify the effects of the interventions with appropriate measurements as well as the cost of other resources before the economic analysis.

In contrast to other studies indicating that older adults have not been fully ready for telehealth [116,117], all our included reviews that assessed the participants’ experiences with and attitudes toward telehealth interventions have demonstrated good acceptance of telehealth among the older population. This difference might be explained by the use of different telehealth modalities in different studies as well as the prescreening process in some studies that excluded older adults who may have difficulty using telehealth. We identified a similar set of factors affecting older adults’ telehealth use as other reviews [118,119], and further categorizing these factors into individual, interpersonal, technological, system, and policy levels could assist in understanding the needs of the older population in this process and identify the potential collaborative efforts that individuals, health care providers, developers of telehealth applications, government and community organizations, and policy makers can make to prepare the older population for digital inclusion. To help older individuals cope with the cultural and psychological challenges associated with digital health technologies, training programs could be offered to both the older population and health care providers to improve their digital literacy as well as skills in interpersonal communication and rapport building. Although there is no “one-size-fits-all” solution, developers of telehealth applications could engage older people, especially those with special needs (eg, those with physical immobility, sensory change, negative affect, cognitive impairment, low digital literacy, or communication barriers), in the user-centered design, testing, and evaluation of telehealth technologies and keep their needs in mind. Health systems should be responsible for ensuring a smooth and continuous clinical workflow with telehealth, along with providing the latest guidelines and health information to health care providers and older patients. Policy makers could enhance clinical guidelines and policies to regulate the design and implementation of telehealth, address privacy concerns, bridge the digital divide, and improve the current payment models so that telehealth could be offered to users with better security, accessibility, and affordability.

Strengths and Limitations
We chose to conduct a scoping review to comprehensively cover a wide range of older subpopulations, telehealth interventions, outcome measures, and types of systematic reviews. Our choice of only including systematic reviews was in response to the rapid growth of telehealth studies and the heterogeneous aims of the systematic reviews of telehealth interventions in the aging care context. Nonetheless, this choice may have neglected the details of the included telehealth interventions as well as the exclusion of some pertinent studies in consideration of their methodology and design. Although we adopted a systematic approach guided by the methodological framework of the Joanna Briggs Institute [22], there might be undetected relevant systematic reviews. The inclusion of only full-text systematic reviews in English may also lead to the loss of sight of those reviews without full-text accessibility. In addition, the low number of systematic reviews with meta-analyses also limits the robustness of the conclusions that can be drawn.

In addition to the methodological limitations, we identified limitations regarding the generalizability of the results. First, most of the studies in the included reviews were conducted in North America, Europe, and Australia, which may limit the generalizability of our findings to the global telehealth market. Second, several reviews have reported that the prescreening process has excluded the older users with special needs (eg, physical immobility, sensory change, negative affect, cognitive impairment, and communication barriers); hence, the results may not be generalizable to these vulnerable groups. Third, we identified different definitions of the population (older adults), interventions (telehealth, telemedicine, and telecare), and outcome measures, which might be because of different search terms, research settings, and geographic locations. This makes it difficult to compare the feasibility, effectiveness, cost, and acceptability of the interventions. Therefore, it is important to standardize and carefully define the terminologies and assessment tools in future research to reduce bias and draw robust and reliable conclusions.

Conclusions
The development and implementation of telehealth have been further catalyzed by the COVID-19 pandemic, and this scoping review has identified considerable evidence of the effectiveness, feasibility, cost benefits, and acceptability of telehealth applications in aging care. Although telehealth remains in its infancy and there is a lack of high-quality studies to draw robust conclusions, mounting evidence indicates that telehealth plays
an important complementary role in the care of the aging population. It is imperative for older individuals, health care providers, developers of telehealth applications, government and community organizations, and policy makers to make a collaborative effort. This could help gain deeper insights into the multifaceted needs of and challenges faced by the older populations; facilitate a user-centered approach in the design and testing of telehealth technologies; and improve the security, accessibility, and affordability by enhancing the existing clinical guidelines and regulations. More high-quality studies are also required to provide a robust evidence base for aging care.

Acknowledgments
The authors would like to thank Ms Yasmin Lynda Munro from the Lee Kong Chian School of Medicine, Medical Library, for assistance in discussing and formulating the search strategy. This research was partially supported by the Physical Education and Sports Science Academic Group, National Institute of Education, Nanyang Technological University, Singapore.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Search strategy and results.
[DOCX File, 32 KB - aging_v6i1e40460_app1.docx]

Multimedia Appendix 2
Characteristics of the included reviews.
[DOCX File, 41 KB - aging_v6i1e40460_app2.docx]

Multimedia Appendix 3
Summary of the conceptual and operational definitions of the terminologies.
[DOCX File, 39 KB - aging_v6i1e40460_app3.docx]

Multimedia Appendix 4
Inclusion and exclusion criteria of the included reviews.
[DOCX File, 43 KB - aging_v6i1e40460_app4.docx]

Multimedia Appendix 5
Summary of the effectiveness outcomes of telehealth.
[DOCX File, 38 KB - aging_v6i1e40460_app5.docx]

Multimedia Appendix 6
Summary of the feasibility outcomes of telehealth.
[DOCX File, 24 KB - aging_v6i1e40460_app6.docx]

Multimedia Appendix 7
Summary of the cost-benefit outcomes of telehealth.
[DOCX File, 27 KB - aging_v6i1e40460_app7.docx]

Multimedia Appendix 8
Summary of the acceptance outcomes with factors affecting telehealth use.
[DOCX File, 33 KB - aging_v6i1e40460_app8.docx]

References
4. NEJM Catalyst. What is telehealth? NEJM Catal 2018 Feb 01;4(1) [FREE Full text]


33. What is telehealth? Center for Connected Health Policy. URL: https://tinyurl.com/y2fvym [accessed 2022-06-05]
38. Sanders JH, Salter PH, Stachura ME. The unique application of telemedicine to the managed healthcare system. Am J Manag Care 1996 May 01;2(5):551-554 [FREE Full text]
46. A health telematics policy in support of WHO's Health-for-all strategy for global health development: report of the WHO group consultation on health telematics. World Health Organization. 1998. URL: https://apps.who.int/iris/bitstream/handle/10665/63857/WHO_DGO_98.1.pdf?sequence=1&isAllo...


Abbreviations

PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analyses
PRISMA-ScR: Preferred Reporting Items for Systematic Review and Meta-Analyses for Scoping Reviews
RCT: randomized controlled trial
Adapting Transportation Planning e-Tools to Older Adults’ Needs: Scoping Review

Sahar Tahir1,2*, MSc; Bessam Abdulrazak1,2*, CEng, PhD; Dany Baillargeon2,3*, PhD; Catherine Girard2,4*, MA; Véronique Provencher2,4*, OTR, PhD

1AMbient Intelligence Lab, Département Informatique, Faculty of Science, University of Sherbrooke, Sherbrooke, QC, Canada
2Research Center on Aging, Centre intégré universitaire de santé et de services sociaux de l’Estrie, Centre hospitalier universitaire de Sherbrooke, Sherbrooke, QC, Canada
3Department of Communication, University of Sherbrooke, Sherbrooke, QC, Canada
4School of Rehabilitation, University of Sherbrooke, Sherbrooke, QC, Canada
*all authors contributed equally

Corresponding Author:
Sahar Tahir, MSc
AMbient Intelligence Lab, Département Informatique
Faculty of Science
University of Sherbrooke
2500 Bd de l’Université
Sherbrooke, QC, J1K 2R1
Canada
Phone: 1 8198218000
Email: Sahar.Tahir@USherbrooke.ca

Abstract

Background: Aging is often accompanied by a decrease in physical and sensory capacities and financial resources, which makes travel and the use of public transport a big challenge for older adults. These mobility limitations may prevent them from going out for groceries, medical appointments, or entertainment, which increases the risk of social isolation. A key element in helping older adults to maintain healthy aging and social engagement is to foster autonomy, freedom, and active mobility. A transportation planning e-tool can provide older adults with information about transport and trip options. There are many transportation planning e-tools, but little is known about whether and how their characteristics and functionalities address older adults’ needs and preferences.

Objective: This study aims to map existing transportation e-tools and identify gaps to be filled in order to match their functionalities with older adults’ needs and preferences.

Methods: A scoping review of existing transportation planning e-tools was conducted based on the approach developed by Arksey and O’Malley. A search in the scientific literature (Academic Search Complete, MEDLINE, CINAHL, SocINDEX, and ERIC) as well as gray literature (TRID Database, Google Scholar, Proquest, Google Play, etc) was conducted in June 2020 and updated 3 times; in September 2021, December 2021, and May 2022. After the studies were selected, a comparative analysis was performed by 2 evaluators; an occupational therapy student and a computer science student. These e-tools were analyzed with respect to some characteristics (eg, tool’s development status, target customers, and geographic coverage) as well as 10 functionalities (time autonomy, walkability, crowd avoidance, incline avoidance, weather consideration, dark avoidance, winter obstacles avoidance, amenities inclusion, taxi driver’s information, and support affordance) that we defined based on older adults’ needs and preferences (mainly Canadians). These needs were identified from a literature review and confirmed by workshops (focus groups).

Results: The scientific and gray literature search yielded 463 sources, and 42 transportation e-tools were included. None of the e-tools reviewed addresses all 10 functionalities. More specifically, functionalities such as dark avoidance and support affordance were not addressed by any of the included e-tools.

Conclusions: Most of the e-tools currently available to plan trips do not address older adults’ needs and preferences. The results of this scoping review helped fill this gap by identifying functionalities to include in transportation planning e-tools designed to...
promote active aging. The findings of this study highlight the need to use a multicriteria optimization algorithm to address older adults’ mobility needs and preferences.

**International Registered Report Identifier (IRRID):** RR2-10.2196/33894

**(JMIR Aging 2023;6:e41938)** doi:10.2196/41938

**KEYWORDS**
active aging, transportation; e-tool; user-centered; review; Canadian mobility experience

**Introduction**

**Background**

According to the World Health Organization [1], the percentage of the population made up of older adults has grown continuously over the years. The Canadian population aged 60 years or older is estimated to be 26% of the total population in 2022 and to reach 31.2% by 2030. Aging is often associated with frailty-related difficulties, including slower walking speed and poorer balance, increasing the risk of falling on icy sidewalks or not having enough time to cross at a traffic light or climb a steep hill [2]. It is challenging for many older adults to use public transport, as they may be reluctant to get on a crowded bus or have difficulty getting on and off the bus [3]. Vision loss may prevent older adults from feeling safe when driving [4,5] while having fewer financial resources often limits the use of taxis [5,6]. As their social network is often restricted, many older adults do not have anyone to help them, for example, to go shopping [5]. In addition, a lack of digital literacy increases their difficulty planning their trips and finding public transportation options [7]. These difficulties and barriers affect older adults’ ability to move around safely and independently and prevent them from maintaining social life as actively as they would like, which is often considered essential to maintaining social connectedness, independence, and a sense of well-being [8,9]. Thus, there is a need to provide accessible and affordable transportation options and support older adults in transportation planning and selecting the means of transport that best fit their needs and preferences [10].

Transportation planning e-tools have become increasingly popular around the world, providing information about different means of transport and helping people get to their destinations quickly and easily [11]. These transportation e-tools may be helpful for basic uses, such as giving directions from a departure point to a destination or identifying the shortest and fastest route or the route with the fewest connections [11]. They can also provide real-time data (eg, bus current location and arrival time), traffic congestion, and route changes. However, little is known about the extent to which existing planning e-tools are tailored to older adults’ unique values surrounding mobility issues and whether they provide safe, independent, and pleasant trips [12,13]. Therefore, there is a need to identify gaps to be filled in order to develop an e-tool that supports active, healthy aging.

**Context and Objectives**

This scoping review was embedded in the first phase of a larger project named Mobilaînês. This project aims to implement a Mobility as a Service (MaaS) e-tool, or, in other words, a 1-stop platform transport service combining different means of transport and various forms of transport services to help older adults move around where, when, and how they want [14]. The Mobilaînês project is supported by LIPPA (Laboratoire d’innovations par et pour les aînés), a laboratory of innovations by and for older adults [14]. Mobilaînês is based on a living laboratory research approach, in which stakeholders from various sectors and fields collaborate to create, validate, and test new technologies, services, products, and systems in real-life contexts [14]. The ultimate aim of Mobilaînês is to promote active aging by helping older adults plan their trips and guiding them to use routes adapted to their needs (eg, avoid hills and snowy sidewalks) and preferences (pass by toilets or benches to take a rest). The aim of this scoping review was to (1) identify existing transportation e-tools designed to help with trips and that provide useful information about the various means of transportation available, (2) evaluate the extent to which their characteristics and functionalities are tailored to older adults’ needs and preferences emerging from the first phase of Mobilaînês [14], and (3) pinpoint research gaps that need to be filled in order to develop an e-tool that supports active, healthy aging.

**Methods**

**Study Design**

The approach used follows the five stages described by Arksey and O’Malley [15]: (1) phrasing the research questions, (2) identifying relevant libraries and sources, (3) selecting interesting transportation e-tools based on defined inclusion and exclusion criteria, (4) charting the data, and (5) summarizing the data and synthesizing the results.

**Phrasing the Research Questions**

This scoping review aimed to answer the following questions:
1. What are the current local, national, and international transportation planning e-tools? What are their characteristics and functionalities?
2. To what extent do these transportation planning e-tools take older adults’ needs and preferences into consideration in order to enhance their independence, sense of well-being, and safety when moving around?

**Identifying Relevant Libraries and Sources**

Relevant libraries and sources were identified by an occupational therapy student and a computer science student involved in the Mobilaînês study. The search included the scientific literature (2015–2022) in 5 databases (Academic Search Complete, MEDLINE, CINAHL, SocINDEX, and ERIC) using the...
following keywords: (transport* OR “public transport”* OR travel OR “public transit” OR “active transport”* OR “alternative transport” OR paratransit OR bus* OR carpool*) AND (“integrated service” OR “mobility as a service” OR “MaaS” OR “mobility information system”* OR “technology as a service” OR “TaaS” OR “intermodal mobility” OR “intermodal transportation”).

To ensure the most up-to-date review of the data, we limited our search to the scientific and gray literature (books, memoirs, and government publications) published in French or English since 2015. Our search was extended to the TRID (Transportation Research International Documentation) Database, Google Scholar, Proquest, Google, and Google Play to identify interesting mobile apps related to transport. Keywords were adapted to each source based on iterative search processes to pinpoint the most accurate and appropriate results. The keywords used for each source are shown in Table 1. Results from the databases and grey literature were exported to a reference manager (Zotero), and duplicates were eliminated.

### Table 1. Keywords used for each source.

<table>
<thead>
<tr>
<th>Source</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRID Database</td>
<td>“integrated service” OR “mobility as a service” OR “MaaS” OR “mobility information system” OR “technology as a service” OR “TaaS” OR “intermodal mobility” OR “intermodal transportation”</td>
</tr>
<tr>
<td>Google Scholar</td>
<td>“Mobility as a service” AND “Canada” AND (“transport” OR “public transport” OR “mobility” OR travel OR “public transit” OR “active transport” OR “alternative transport” OR “paratransit” OR “bus” OR “carpool”) AND (“integrated service” OR “mobility as a service” OR “mobility information system” OR “technology as a service” OR “intermodal mobility” OR “intermodal transportation”).</td>
</tr>
<tr>
<td>Proquest</td>
<td>“Outil planification déplacement” (French), “Mobility as a service”</td>
</tr>
<tr>
<td>Google</td>
<td>“Outil planification déplacement” AND “Aide déplacement” AND “Outil aide mobilité” AND “Assistance déplacement” AND “Transport personnes âgées” (French) AND “Mobility as a service” + “for seniors” AND “Dial a ride” AND “Mobility on demand”</td>
</tr>
<tr>
<td>Google App Store or Play</td>
<td>“Déplacement” AND “Mobilité” (French) AND “Transport” AND “Assistive technology”</td>
</tr>
</tbody>
</table>

Selecting Interesting Transportation e-Tools—Inclusion and Exclusion Criteria

Relevant sources were selected by 2 research assistants from different disciplines (occupational therapy and engineering). First, sources were screened by title and included if they (1) introduced a transportation tool or included a state-of-the-art section about transportation e-tools or (2) combined different available means of transport. Sources were then screened by abstract when available. The initial search yielded 463 sources: Academic Search Complete (n=215), MEDLINE with full text (n=30), CINAHL Plus with full text (n=14), SocINDEX with full text (n=3), ERIC (n=2), Transportation Research Board (n=104), Google Scholar (n=10), Google (n=18), Google App Store or Play (n=61), and scientific papers and conference proceedings recommended by team members (n=6). After removing duplicates, 421 publications remained, of which 379 did not meet the inclusion criteria according to title and abstract screening. Ultimately, 42 sources met the criteria defined above and were included in the full-text analysis.

Charting the Data

The transportation planning e-tools selected were then charted in an Excel (Microsoft Corp) sheet by 2 research assistants (students in computer science and occupational therapy), according to the following characteristics: (1) transportation tool name, (2) tool’s development status, (3) tool’s interface, (4) target customers, (5) geographic coverage, and (6) cost for users. To achieve our objectives, we evaluated the selected e-tools according to a set of 7 values related to older adults’ mobility. This set of 7 values was determined by the research team (see protocol [14]) based on (1) an inventory of core values [16], and (2) older adults’ mobility needs and preferences, identified from the literature review and 6 individual phone interviews conducted during the first phase of Mobileinfès in Sherbrooke, Quebec, Canada. The following are the seven values:

1. Eco responsibility and environmental preferences: they have a great impact on older adults’ choice of means of transport. In this context, Vredin Johansson et al [17] maintained that “...environmental preferences increase the likelihood of choosing an environmentally friendly mode over a less environmentally friendly mode.”
2. Health: it is viewed by older adults as a state of physical, mental, spiritual, and social well-being. Daily mobility is a kind of exercise for older adults that helps them maintain an active and healthy lifestyle [14,18].
3. Safety: it is the protection of older adults’ physical, emotional, and psychological integrity. Safety concerns can create a fear of crime [19], accidents, harassment, and so on, as well as misbehavior by staff [20]. This anxiety prevents older adults from using public transportation.
4. Quality of life: a lack of transportation has a major impact on older adults’ satisfaction and sense of personal well-being. According to Kim and Ulfarsson [21], “...mobility is significantly associated with quality of life among older people.” Metz [18] highlighted the destination-dependent and psychological benefits of mobility.
5. Equality: it is vital to give the same consideration to promoting the mobility of all older adults. Bourgault-Brunelle [22] showed that there is a diversity of
transportation services in administrative regions (of Quebec in our case), and these services are not accessible to everyone; it seems that some regions or subregions are not served as well as others. Fiedler and Consult [20] also proved that language and cultural barriers often prevent older adults from suitably using public transportation.

6. Functional autonomy: this refers to older adults’ ability to carry out their daily activities in their physical, social, institutional, and cultural environments.

7. Decision-making autonomy: this refers to older adults’ involvement in decisions that affect them. In this context, Shrestha et al [23] maintained that public transport plays a crucial role in older adults’ freedom and independence, and “access to public transport can help older adults to avail themselves of goods, services, employment, and other activities.”

These 7 values were then translated into 9 statements that an adapted transportation system for older adults should ideally satisfy (Table 2). To do so, 6 phone interviews with frail older adults were conducted in order to identify facilitators and barriers to mobility (when planning trips and moving around) and document previous experiences. These phone interviews were transcribed and coded, and later on, the outcome was classified into mobility facilitators and barriers by 2 project team members and then covalidated by 2 researchers [24]. Emerging themes were compared with data from 2 workshops on mobility facilitators and barriers (see research protocol) [8]. Recurrent themes were finally analyzed by the research team to generate the Mobilaînës statements (Table 2).

A survey was sent to the steering committee members (stakeholders from the public, scientific, and community sectors who work with or study the older adult population) [8] and LIPPA’s older adults committee to validate and classify these statements according to their importance and impact on promoting active aging. Gaps between the 2 group classifications were discussed during a steering committee meeting to decide the final classification: 9 statements were classified as important, recommended, or not important. The resultant statements and the corresponding values, as well as the steering committee members’ and older adults’ classifications of these statements, are presented in Table 2.

The survey results support the relevance of co-designing a transportation tool that would offer a safe journey and routes and interfaces adapted to the physical, sensory, and cultural needs of older adults. Interactions with older adults through co-design workshops highlighted the importance of providing an easy-to-use platform and considering key elements such as the weather, especially for trips that require you to arrive at a specific time. Exploration of new travel experiences was identified as not important by both partners and the older adults committee.

To translate these statements into more technical and measurable functionalities, 2 “in-person” workshop sessions with transportation service providers and 2 others with older citizens (n=8) were conducted. In total, 10 relevant functionalities (see Table 3) were kept after the research team’s analysis and after discussion and validation by the steering committee members. These 10 functionalities are considered to be what an ideal transportation tool should provide to address older adults’ needs and preferences.

Table 2. Statements that a transportation tool should ideally satisfy.

<table>
<thead>
<tr>
<th>Statement: Transportation tool should…</th>
<th>Values</th>
<th>Partners’ classification</th>
<th>Older adults’ classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consider the values of sustainable and eco-responsible mobility</td>
<td>1</td>
<td>Recommended</td>
<td>Recommended</td>
</tr>
<tr>
<td>Suggest a route adapted to older adults</td>
<td>3,6</td>
<td>Important</td>
<td>Important</td>
</tr>
<tr>
<td>Suggest a pleasant route</td>
<td>4</td>
<td>Important</td>
<td>Recommended</td>
</tr>
<tr>
<td>Be adapted and accessible to people with limitations (hearing, visual, cognitive, reading difficulties or facing linguistic or cultural barriers)</td>
<td>5,6</td>
<td>Important</td>
<td>Important</td>
</tr>
<tr>
<td>Foster active mobility</td>
<td>2,4</td>
<td>Recommended</td>
<td>Recommended</td>
</tr>
<tr>
<td>Suggest a safe journey</td>
<td>3,4,6</td>
<td>Important</td>
<td>Important</td>
</tr>
<tr>
<td>Be useful for more rural communities</td>
<td>5,6</td>
<td>Recommended</td>
<td>Recommended</td>
</tr>
<tr>
<td>Consider travel costs to support decision-making</td>
<td>3,5,6</td>
<td>Recommended</td>
<td>Important</td>
</tr>
<tr>
<td>Encourage the exploration of new travel experiences</td>
<td>4,6</td>
<td>Not important</td>
<td>Not important</td>
</tr>
</tbody>
</table>
Table 3. Relevant functionalities an ideal transportation tool should provide.

<table>
<thead>
<tr>
<th>Number</th>
<th>Functionalities</th>
<th>Older adults’ interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Time autonomy</td>
<td>I want to go out whenever I want (now, tomorrow, etc)</td>
</tr>
<tr>
<td>2</td>
<td>Walkability</td>
<td>I want to avoid walking or take my walking speed into account when planning trips</td>
</tr>
<tr>
<td>3</td>
<td>Crowd avoidance</td>
<td>I want to avoid crowded routes and places</td>
</tr>
<tr>
<td>4</td>
<td>Incline avoidance</td>
<td>I want to avoid hills</td>
</tr>
<tr>
<td>5</td>
<td>Weather consideration</td>
<td>I want to avoid going out when the weather is hot or wet</td>
</tr>
<tr>
<td>6</td>
<td>Dark avoidance</td>
<td>I want to avoid going out when it’s dark</td>
</tr>
<tr>
<td>7</td>
<td>Winter obstacle avoidance</td>
<td>I want to avoid icy sidewalks or icy roads</td>
</tr>
<tr>
<td>8</td>
<td>Amenities inclusion</td>
<td>I want information about relevant amenities on my route (toilet, bench, bus shelter, public telephone, etc)</td>
</tr>
<tr>
<td>9</td>
<td>Taxi driver’s information</td>
<td>I want to know who is going to pick me up, what type of car, especially for a taxi</td>
</tr>
<tr>
<td>10</td>
<td>Support affordance</td>
<td>I need some support (providing company, helping with bags and to get into, onto, and out of or off vehicles)</td>
</tr>
</tbody>
</table>

Results

Characteristics of the e-Tools

A total of 42 transportation e-tools were included in this scoping review: 37 are accessible via mobile apps (Android or iOS) and web platforms, along with 4 prototypes and 1 web platform (Figure 1). The e-tools included did not target a specific population, except for 3 of the prototypes, namely Path2.0 [25], mPASS [26], and Mobility in Later Life [27], which were designed for people with disabilities, pedestrians, and older adults, respectively. Two e-tools (STS [28] and Embarque Estrie [29]) cover the region where the study took place (the city of Sherbrooke, Quebec, Canada), while 4 e-tools cover other cities in Quebec (the Montreal area for Chrono [30], STL Synchro+ [31], and TripGo [32], the province of Quebec for Exo Quebec [33]), and 2 cover cities in another Canadian province, Ontario (OC Transpo [34] in Ottawa and Triplinx in Toronto). While 27 e-tools are for use in different cities and countries in Europe, 6 e-tools (Transit [35], Moovit [36], CityMapper [37], GoogleMaps [38], HERE WeGo [39], and Transperth [40]) can be used in different cities around the world. Most of the e-tools reviewed (n=38) consider public transport: 7 consider only bus while others consider rail, tramway, and bus. All of the e-tools reviewed suggest walking paths, 29 suggest bike paths, 8 suggest bike sharing, and 10 e-tools redirect users to ride-sharing websites or apps for ride-sharing routes. The same is true for taxi routes, which are included in 4 of the e-tools reviewed. Three e-tools redirect people to Uber for rides. Twenty e-tools suggest riding (car) paths. Five e-tools suggest paths for kick scooters, but only 1 tool suggests paths for motorbikes. All the transportation e-tools reviewed are free to install and use, except for Transit [35] and Whiz [41], which charge fees for additional personalization and more functionalities.
Functionalities of the e-Tools

Following is our analysis of the e-tools in relation to the 10 functionalities.

- **Functionality 1 (Time autonomy):** all of the e-tools reviewed, except for 5 [25–27,29,42], which do not give any details about time, allow users to set a departure time and depart whenever they want. Embarque Estrie [29] does not give a choice of departure time (it shows alternate routes without further details about time), while no details were given for this functionality in the 4 prototypes examined (mPASS [26], Path2.0 [25], Sway [42], and Mobility in Later Life [27]).

- **Functionality 2 (Walkability):** twelve of the e-tools provide the option of minimizing distance or walking. Eleven e-tools ask users to choose their walking speed or to set the maximum walking distance tolerated, or both (walking speed and maximum walking distance tolerated). Path2.0 [25] is a prototype that stores accessible routes for people with disabilities so these routes could be recommended for the next trip; this could also be applied to walking speed.

- **Functionality 3 (Crowd avoidance):** five of the e-tools reviewed give information about road traffic. Three e-tools give real-time data about free parking places or an estimate of the crowd on the bus, while only one, Google Maps [38], provides an estimate of available seats in addition to estimated traffic for bus and road trips.

- **Functionality 4 (Incline avoidance):** inclines were not considered by most of the e-tools reviewed, except for Transp’Or [43], which suggests balanced and bike-adapted paths. Martinique mobilités [44], Irigo [45], and Tac mobilités [46] show the bike path’s elevation. Additionally, Irigo [45] and Tac mobilités [46] show the percentage of cyclable, normal, and dangerous lanes in bike paths. The prototype mPASS [26] provides personalized maps and adapted routes that consider users’ needs. For example, inclines can be considered a barrier about which data will be collected through sources (crowdsourcing, sensing, and expert data), so they can be considered when route planning. Stairs were considered in the case study of testing the prototype. Sway [42] considers the criterion of comfort when planning a route through incline avoidance.

- **Functionality 5 (Weather consideration):** most of the e-tools reviewed do not consider the weather, except for 4 e-tools [27,34,42,47] that give the temperature.

- **Functionality 6 (Dark avoidance):** this functionality was not considered by any of the e-tools reviewed.

- **Functionality 7 (Winter obstacle avoidance):** similar to Functionality 4, icy sidewalks were not considered by any of the e-tools reviewed, except for mPASS [26], a prototype that provides personalized maps and adapted routes that consider users’ needs. For example, icy sidewalks can be considered a barrier about which data will be collected through sources (crowdsourcing, sensing, and expert data), so they can be considered when route planning. Stairs were considered in the case study of testing the prototype. Sway [42] considers the criterion of comfort when planning a route through incline avoidance.

- **Functionality 8 (Amenities inclusion):** relevant amenities and services (eg, bus stations, parks, hospitals, universities, and parking) available near a given address are provided by 7 e-tools, while Embarque Estrie [29] gives relevant places near the departure and arrival addresses. Toilets and benches were not considered by any of the e-tools reviewed, except for mPASS [26], where toilets and benches can be considered facilities to take into account in route planning.
Ramps and curb cuts were considered in the case study of testing the prototype.

- Functionality 9 (taxi driver’s information): none of the e-tools reviewed includes this information, except for 3 e-tools (Transit [35], OiseMobilité [48], and Go!Vermont [49]) that redirect users who choose ride-sharing to another app that gives details about the carpooler, and Mobility in Later Life [27], which shows the carpool route and details about the carpooler.

- Functionality 10 (Support affordance): none of the e-tools reviewed has the option of getting support (providing company, helping with bags, and to get into, onto, and out of or off vehicles).

Table 4 summarizes further details.

Table 4. Operationalization of defined functionalities by the e-tools reviewed.

<table>
<thead>
<tr>
<th>Functionality and how this is addressed by the e-tools in this scoping review</th>
<th>Tool references</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time autonomy: provide the option of choosing a departure date and time</td>
<td>[27,28,30-66]</td>
</tr>
<tr>
<td><strong>Walkability</strong></td>
<td></td>
</tr>
<tr>
<td>Provide the option of minimizing distance or walking</td>
<td>[31,33,35,36,38,41,48,52,59,62,65,66]</td>
</tr>
<tr>
<td>Store accessible routes for people with disabilities so these routes could be recommended for the next trip</td>
<td>[25]</td>
</tr>
<tr>
<td>Consider the maximum distance tolerated by the user</td>
<td>[28,40,47,51,52,57,66]</td>
</tr>
<tr>
<td>Consider the walking speed indicated by the use in route planning</td>
<td>[28,40,44-48,52,56,57,63,66]</td>
</tr>
<tr>
<td><strong>Crowd avoidance</strong></td>
<td></td>
</tr>
<tr>
<td>Provide information about road traffic or parking</td>
<td>[38,39,47,49,50,54]</td>
</tr>
<tr>
<td>Provide an estimate of the crowd on the bus</td>
<td>[38,61,63]</td>
</tr>
<tr>
<td>Provide an estimate of the crowd at the destination</td>
<td>[38]</td>
</tr>
<tr>
<td><strong>Incline avoidance</strong></td>
<td></td>
</tr>
<tr>
<td>Consider inclines a barrier to avoid; data about inclines could be collected through crowdsourcing, available data provided by experts</td>
<td>[26]</td>
</tr>
<tr>
<td>Provide balanced and adapted routes for biking</td>
<td>[37,43]</td>
</tr>
<tr>
<td>Consider the criterion of comfort</td>
<td>[42]</td>
</tr>
<tr>
<td>Show the bike path’s elevation</td>
<td>[44-47,52,54,59]</td>
</tr>
<tr>
<td>Show the percentage of cyclable, normal, and dangerous lanes in bike paths</td>
<td>[45,46,52,54]</td>
</tr>
<tr>
<td>Weather: display information about the temperature</td>
<td>[27,34,39,42,47]</td>
</tr>
<tr>
<td>Dark avoidance: none</td>
<td>None</td>
</tr>
<tr>
<td>Winter obstacle avoidance: consider icy sidewalks a barrier to avoid; data about icy sidewalks could be collected through crowdsourcing, available data provided by experts</td>
<td>[26]</td>
</tr>
<tr>
<td><strong>Amenities inclusion</strong></td>
<td></td>
</tr>
<tr>
<td>Have the option next to the user that gives relevant amenities (bus stations, parking, hospitals, universities, parks, administrations, etc) near the address given</td>
<td>[28,48,53,55,59,60]</td>
</tr>
<tr>
<td>Show users relevant amenities (bus stations, bike stations, parking, etc) within 500 m of departure and destination locations</td>
<td>[29]</td>
</tr>
<tr>
<td>Consider toilets and bench facilities to take into account; data about toilets could be collected through crowdsourcing, and available data provided by experts</td>
<td>[26]</td>
</tr>
<tr>
<td>Taxi driver’s information: in the case of ride-sharing, redirect users to the ride-sharing app containing further details about the carpooler, such as the person’s name and type of car</td>
<td>[35,48,49]</td>
</tr>
<tr>
<td>Support affordance: none</td>
<td>None</td>
</tr>
</tbody>
</table>

**Discussion**

**Principal Findings**

The aim of this scoping review was to explore the scientific and gray literature in order to identify existing transportation planning e-tools and evaluate the extent to which their characteristics and functionalities are tailored to older adults’ needs and preferences. Although many transportation planning e-tools have been developed to help people reach their destination using different means of transport (car, taxi, bus, car sharing, bicycle, walking, etc) and to give them various details about the trip (eg, directions, which bus to take, and which station), most of the existing e-tools focus on the functionalities for the shortest or fastest route or the route with the fewest transfers and consider only 1 criterion (distance, time,
or the number of transfers). However, based on the Mobilainè project workshops, older adults did not find these functionalities (shortest or fastest route) to be very important. Furthermore, older adults’ needs with respect to avoiding winter obstacles and inclines were not taken into consideration in most of the e-tools reviewed. In general, workshop results show that weather conditions are considered by older adults when making decisions about transportation means, the time of the day, and the reason they travel. This finding is consistent with those of Stein et al [27]. Incline avoidance was considered only for bike paths by 8 e-tools. The only exceptions are mPASS [26], which considers icy sidewalks and inclines as barriers to avoid in route planning, and Sway [42], which considers the criterion of comfort. Moreover, few e-tools provide functionalities that might help older adults who have difficulty walking. Transit [35] proposes routes without stairs, while VaNavigo [56], RATP [61], and Path2.0 [25] suggest accessible routes for people with reduced mobility using wheelchairs. In this context, TripGo [32] provides 6 alternatives (recommended, greenest, easiest, fastest, healthiest, and cheapest) (see Multimedia Appendix 1 for further details).

To foster older adults’ mobility, identified gaps (eg, help to get into or onto, and out of or off vehicles and with bags or a walker), awareness of accessible amenities (eg, toilets and restaurants) as brought up by Stein et al [27], and information about whether it will be dark during the return trip) should be considered in the Mobilainè platform to fulfill their needs and preferences. Furthermore, since older adults’ needs and preferences may differ from one person to the next, multicriteria optimization algorithms may be a promising way to personalize mobility [27]. To contribute to healthy aging, there is a great need for a transportation planning tool that provides personalized maps with textual and graphic presentation and routes adapted to older adults’ physical and sensory impairments and cognitive capacities [5].

Limitations
This study has some limitations; for example, some articles may not have been retrieved (due to the chosen keywords). Including prototypes in our scoping review is also a limitation of our analysis because these e-tools are not accessible and could not be tested. Furthermore, not including transportation planning e-tools that use only one mode may be a limitation because they may have some interesting functionalities for an e-tool involving only one mode of transport.

Conclusions
This scoping review identified gaps that should be addressed to produce transportation planning e-tools that aim to promote active and independent aging. The results of this scoping review will be useful in designing a personalized multimodal planning tool, such as Mobilainè, to help older adults select a route that takes their needs and preferences into account. Further research is needed to determine whether data related to the functionalities identified are available or must be created to develop a transportation planning tool in line with older adults’ values. Challenges that remain concerning include which approaches to take in terms of routing algorithms, optimization criteria, and the importance of each of the criteria considered in order to find suitable routes for older adults and make these e-tools readily accessible to users with limited digital literacy.

Acknowledgments
The authors wish to acknowledge the valuable contribution to this study of the older adults and students involved, especially Evelyne Laroche, who helped with the scoping review, as well as all the partner-members of the steering committee, namely Sylvie Gilbert Fowlis (LIPPA committee), Sylvie Lebrun (the Eastern Townships older adults’ regional consultation table), Julien Mole Verderosa (Sherbrooke Healthy City), Mali Prud’homme (Sage-Innovation), and Line Coutu (a senior citizen). We thank our collaborators Caroline Proulx, Martin Brochu, Suzanne Garon, Jean-François Comeau, Mathieu Hamel, Isabelle Lacroix, and Mélissa Généreux, as well as our other partners Accélérateur de création d'entreprises technologiques (ACET–Banque Nationale), Centre intégré universitaire de santé et de services sociaux de l’Estrie–Centre hospitalier universitaire de Sherbrooke, Corporation de développement communautaire de Sherbrooke–Solidarité Transport, the Public Health Agency of Canada, Sercovie, and Société de transport de Sherbrooke—for their support in developing this project. We also thank the Fonds de recherche du Québec–Santé for its financial support.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Functionalities of the reviewed e-tools.

References
1. Percentage of total population aged 60 years or over. World Health Organization. URL: https://www.who.int/data/maternal-newborn-child-adolescent-ageing/documents/mca [accessed 2021-11-11]


13. Babka RJ, Cooper JF, Ragland DR. Evaluation of an urban travel training for older adults. UC Berkeley Research Reports. 2009. URL: https://escholarship.org/content/qt16k3j6r3/qt16k3j6r3.pdf [accessed 2023-04-04]


29. Embarque Estrie. URL: https://embarqueestrie.ca/ [accessed 2022-05-29]

30. Chrono. URL: https://www.arternquebec/application-mobile-chrono/ [accessed 2021-02-08]


33. Exo. URL: https://exo.quebec/fr [accessed 2021-02-08]
34. OC Transpo. URL: https://www.octranspo.com/en/ [accessed 2021-02-08]
38. Google Maps. URL: https://www.google.ca/maps [accessed 2021-10-19]
39. HERE WeGo. URL: https://wegomap.com/ [accessed 2021-10-19]
46. Mobilité. URL: https://www.mobilitie.it/it/ [accessed 2021-10-19]
47. Oise Mobilités. URL: http://www.oise-mobilite.fr/ [accessed 2021-10-19]
49. M - Mobilité. URL: http://www.mobilites-m.fr/siv.html [accessed 2021-10-19]
50. RTM | Régie des transports Métropolitains. URL: https://www.rtm.fr/ [accessed 2021-10-19]
51. LE MET. URL: https://www.lemet.fr/ [accessed 2021-10-19]
52. Hauts-de-France Mobilités. URL: http://www.hdfrmobilites.fr/les-services/ [accessed 2021-10-19]
53. Modalis. URL: https://modalis.fr/fr/ [accessed 2021-10-19]
54. Divia. URL: https://www.divia.fr/bus-tram [accessed 2021-10-19]
56. Alternéo. URL: https://www.alterneo.fr/ [accessed 2021-10-19]
58. vrd-mobilites. URL: https://www.vrd-mobilites.fr/ [accessed 2021-10-19]
59. Oùra. URL: https://www.oura.com/ [accessed 2021-10-19]
60. RATP. URL: https://www.ratp.fr/ [accessed 2021-02-08]
62. MOBIGO. URL: https://www.viamobigo.fr/ [accessed 2021-10-19]
63. GVH. URL: https://www.gvh.de/fahrplan/auskunft/ [accessed 2021-10-19]

Abbreviations

LIPPA: Laboratoire d’innovations par et pour les aînés
MaaS: Mobility as a Service
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Review

The Experiences of Informal Caregivers of People With Dementia in Web-Based Psychoeducation Programs: Systematic Review and Metasynthesis

Ying Yu¹, RN, MN; Lily Xiao¹, RN, PhD; Shahid Ullah², PhD; Claudia Meyer³,⁴,⁵, PhD; Jing Wang⁶, RN, PhD; Anne Margriet Pot⁷,⁸, PhD; Fathimath Shifaza¹, RN, PhD

¹College of Nursing and Health Sciences, Flinders University, South Australia, Australia
²College of Medicine and Public Health, Flinders University, Bedford Park, South Australia, Australia
³Bolton Clarke Research Institute, Melbourne, Victoria, Australia
⁴Ageing and Independent Living Research Centre, Monash University, Melbourne, Victoria, Australia
⁵Centre for Health Communication and Participation, La Trobe University, Melbourne, Victoria, Australia
⁶Faculty of Nursing, Health Science Center, Xi'an Jiaotong University, Xi'an, Shanxi, China
⁷Erasmus School of Health Policy & Management, Erasmus University Amsterdam, Amsterdam, Netherlands
⁸Optentia, North-West University, Vanderbijlpark, South Africa

Corresponding Author:
Lily Xiao, RN, PhD
College of Nursing and Health Sciences
Flinders University
Sturt Rd
Bedford Park
South Australia, 5042
Australia
Phone: 61 8 82013419
Fax: 61 8 82761602
Email: lily.xiao@flinders.edu.au

Abstract

Background: Informal caregivers of people living with dementia experience a higher level of physical and mental stress compared with other types of caregivers. Psychoeducation programs are viewed as beneficial for building caregivers’ knowledge and skills and for decreasing caregiver stress.

Objective: This review aimed to synthesize the experiences and perceptions of informal caregivers of people with dementia when participating in web-based psychoeducation programs and the factors that enable and impede informal caregivers’ engagement in web-based psychoeducation programs.

Methods: This review followed the Joanna Briggs Institute protocol of systematic review and meta-aggregation of qualitative studies. We searched 4 English databases, 4 Chinese databases, and 1 Arabic database in July 2021.

Results: A total of 9 studies written in English were included in this review. From these studies, 87 findings were extracted and grouped into 20 categories. These categories were further synthesized into 5 findings: web-based learning as an empowering experience, peer support, satisfactory and unsatisfactory program content, satisfactory and unsatisfactory technical design, and challenges encountered in web-based learning.

Conclusions: High-quality and carefully designed web-based psychoeducation programs offered positive experiences for informal caregivers of people living with dementia. To meet broader caregiver education and support needs, program developers should consider information quality and relevancy, the support offered, individual needs, flexibility in delivery, and connectedness between peers and program facilitators.

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KEYWORDS
informal caregivers; dementia; psychoeducation; online; web based; qualitative research; systematic review; metasynthesis

https://aging.jmir.org/2023/1/e47152
**Introduction**

Dementia is a major cause of disability among older adults worldwide [1]. People living with dementia have complex care needs and are often highly dependent on others to care for them [2]. Most people living with dementia are cared for by unpaid informal caregivers who are their family members or friends. Worldwide, in 2019, informal caregivers spent approximately 5 hours per day per person with dementia assisting in daily living activities [2]. They experienced a higher level of physical and mental stress compared with other types of caregivers; showed increased caregiver burden, anxiety, and depression; and showed decreased quality of life [3-5]. Such caregiving situations directly impact the caregiver’s ability to provide quality care.

Early educational interventions to prepare informal caregivers for their role are crucial [2,6]. However, the educational interventions offered do not always meet their needs. Informal caregivers often feel that they lack knowledge of dementia progression and symptom management and the skills for providing daily care [7,8]. They also expressed the need for more support at home from trained health professionals [9] that could foster knowledge sharing; build skills, such as symptom management and physical care; and provide emotional support [10,11].

Psychoeducation programs are viewed as beneficial for meeting caregivers’ expectations and learning needs through knowledge and skill building, while encouraging positive thoughts, decreasing caregiver stress, and improving caregivers’ psychological well-being and quality of life [12]. According to Cheng et al [12], psychoeducation programs usually incorporate theoretical, psychological, and behavioral training components relevant to dementia care to achieve these benefits. Traditionally, psychoeducation programs are delivered face-to-face in small groups [12]. Web-based psychoeducation programs have been widely used in recent years to offer convenience and flexibility to increase caregivers’ participation and retention [13-15]. However, many informal caregivers reported a lack of time or flexibility to commit to these programs because of care responsibilities [16].

Despite the known advantages of web-based psychoeducation for caregivers, underutilization and a lack of program trustworthiness have been identified [2]. Furthermore, studies have revealed a high dropout rate among caregivers in web-based psychoeducation programs [17]. The reasons for the high dropout rate varied across studies and programs. For example, the low recruitment and retention rates reported in a study by Baruah et al [18] indicated a need for further adaptations to the program to improve acceptability and accessibility. Whereas, other studies have indicated that gender [19], program length [20], and uncertain factors [21] contributed to the dropout rate. There is a need to synthesize studies on caregivers’ experiences of using web-based psychoeducation programs to gain further insights into their experiences and facilitators affecting participation in a global context. This review addresses this gap in the literature.

This review aims to synthesize (1) the experiences and perceptions of informal caregivers of people with dementia when participating in web-based psychoeducation programs and (2) the factors that enable and impede informal caregivers’ engagement in web-based psychoeducation programs.

**Methods**

**Inclusion and Exclusion Criteria**

This review included studies that reported components of the experiences of informal caregivers of people living with dementia when using web-based psychoeducation programs in a home care setting. The review included qualitative studies and mixed methods studies that included qualitative components. The following studies were excluded from the review: (1) quantitative design; (2) web-based programs without an educational component, such as social support groups (ie, singing group) and telehealth; (3) non–internet-based programs, such as a DVD or booklet; (4) the population of interest in the study was people with dementia in residential care or hospital settings, rather than home care settings; and (5) not written in English, Chinese, or Arabic (because of team members’ backgrounds).

**Search Strategy and Screening Method**

Keywords were identified according to the study’s population (informal caregivers of people living with dementia), interest (web-based psychoeducation program), and context (home care setting; Multimedia Appendix 1). A Boolean search was conducted by combining keywords. The following English databases were searched in July 2021: CINAHL, Web of Science, MEDLINE, and Scopus (Multimedia Appendix 2). Keywords were translated into Chinese (by YY) and Arabic (by FS) by the review team. The Chinese databases searched included the China National Knowledge Infrastructure, Wang Fang Data, Weipu Data, and Chaoxing Data. We also manually searched the Academic Journal of the Middle East for articles written in Arabic. No time limit was applied to the search. All retrieved records were imported into EndNote 20 [22] and Covidence [23] to remove duplicate studies. In total, 4 reviewers (YY, LX, CM, and SU) screened the English titles and abstracts. In addition, 2 reviewers (YY and JW) screened the Chinese titles and abstracts to identify studies that met the inclusion criteria, and 2 reviewers (YY and LX) reviewed the full text retrieved. The reference list of each selected article was scanned manually.

**Assessment of Methodology**

The methodology of all selected papers was assessed using Joanna Briggs Institute (JBI) critical appraisal instruments for qualitative research [24]. The review team decided to include only those studies that satisfied >5 appraisal questions. The main findings from each paper were critiqued by 2 reviewers to evaluate the level of credibility (ranked as unequivocal, credible, or not supported) according to JBI [24]. The final synthesized findings were derived from unequivocal (findings and supporting data are beyond reasonable doubt and therefore not open to challenge) and credible (findings and supporting data lack clear association and are therefore open to challenge).
findings. Throughout the quality assessment process, disagreements between any 2 reviewers were resolved either through comparison and discussion between the reviewers or through a third reviewer.

Data Extraction
Qualitative data were extracted by 2 reviewers (anonymized for peer review) using the standardized data extraction tool from JBI Qualitative Assessment and Review Instrument [24]. The tool includes (1) author, publication year, and country; (2) participants’ characteristics and sample size; (3) web-based education or training program details, including duration, facilitator details, and theoretical framework; (4) study setting, design, and methods; and (5) main findings. The main findings from each study were extracted with an illustration to evaluate the credibility of the findings (Multimedia Appendix 3) [25-33].

Data Synthesis and Reporting
Data synthesis in this review followed the JBI protocol of meta-aggregation of qualitative studies [24], with the following three steps: (1) the main findings from each study were reviewed by 2 reviewers to evaluate the level of credibility, with unequivocal and credible findings included in the data synthesis and meta-aggregation; (2) similar findings were grouped into categories; and (3) categories were refined and synthesized into final findings. The final findings were reported following PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 [34] (Multimedia Appendix 4).

Results
Study Inclusion
A total of 6168 articles were initially identified from database searches and uploaded to Covidence [23] (English databases, n=5163; Chinese databases, n=1005; and Arabic database, n=0). Covidence automatically removed duplicates (n=2422). Duplicates were manually removed from the Chinese database (n=350). After a title and abstract screening (English, n=2721; Chinese, n=655; and Arabic, n=0), 128 (English, n=117 and Chinese, n=11) full-text articles were retrieved. An additional 12 articles were identified from the searching the reference list of the included articles. After assessing the eligibility of full-text articles, 9 studies written in English met the inclusion criteria and were included for methodology assessment. No articles written in Chinese or Arabic met the inclusion criteria. The study selection process is illustrated in Figure 1.

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram. CNKI: China National Knowledge Infrastructure.
Methodology Quality

The methodological quality of the 9 selected studies was assessed and is presented in Table 1. Of the 9 studies reviewed, 5 (56%) were mixed methods studies and 4 (44%) were qualitative studies. Only 1 study indicated the philosophical perspectives underpinning the methodology [25]. In total, 3 studies were not clear about the cultural and theoretical orientations of the researcher [26-28], and 5 studies did not address the researchers’ influence on the study [26,27,29-31]. Moreover, 1 study only selected 2 cases to represent the qualitative data collected [30]. Therefore, the adequate representation of the participants in that study is questionable. All studies, except 1, indicated participation in an ethics review [27]. No studies were excluded from this review based on the methodological quality assessment.

Table 1. Quality appraisal for qualitative studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Q1&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Q2&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Q3&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Q4&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Q5&lt;sup&gt;e&lt;/sup&gt;</th>
<th>Q6&lt;sup&gt;f&lt;/sup&gt;</th>
<th>Q7&lt;sup&gt;g&lt;/sup&gt;</th>
<th>Q8&lt;sup&gt;h&lt;/sup&gt;</th>
<th>Q9&lt;sup&gt;i&lt;/sup&gt;</th>
<th>Q10&lt;sup&gt;k&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>Brennan et al [29]</td>
<td>U&lt;sup&gt;l&lt;/sup&gt;</td>
<td>Y&lt;sup&gt;m&lt;/sup&gt;</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>U</td>
<td>Y</td>
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<td>Y</td>
</tr>
<tr>
<td>Duggleby et al [33]</td>
<td>U</td>
<td>Y</td>
<td>Y</td>
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<td>Y</td>
<td>U</td>
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<tr>
<td>Fowler et al [30]</td>
<td>U</td>
<td>Y</td>
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<td>Gaugler et al [26]</td>
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<tr>
<td>Halbach et al [27]</td>
<td>U</td>
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<tr>
<td>Hattink et al [28]</td>
<td>U</td>
<td>Y</td>
<td>Y</td>
<td>U</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td>Y</td>
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<tr>
<td>Kovaleva et al [31]</td>
<td>U</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>U</td>
<td>U</td>
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<tr>
<td>Lewis et al [32]</td>
<td>Y</td>
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<tr>
<td>Ploeg et al [25]</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
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<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

<sup>a</sup>Q: question.
<sup>b</sup>Q1: Is there congruity between the stated philosophical perspective and the research methodology?
<sup>c</sup>Q2: Is there congruity between the research methodology and the research question or objectives?
<sup>d</sup>Q3: Is there congruity between the research methodology and the methods used to collect data?
<sup>e</sup>Q4: Is there congruity between the research methodology and the representation and analysis of data?
<sup>f</sup>Q5: Is there congruity between the research methodology and the interpretation of results?
<sup>g</sup>Q6: Is there a statement locating the researcher culturally or theoretically?
<sup>h</sup>Q7: Is the influence of the researcher on the research, and vice versa, addressed?
<sup>i</sup>Q8: Are participants, and their voices, adequately represented?
<sup>j</sup>Q9: Is the research ethical according to the current criteria or, for recent studies, and is there evidence of ethics approval by an appropriate body?
<sup>k</sup>Q10: Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?

Characteristics of the Included Studies

The included studies were published between 1991 and 2019 and were conducted in the United States (n=5), Canada (n=2), the Netherlands (n=1), and Norway (n=1; Table 2). A total of 367 people participated in the qualitative component of these studies. Among the included studies, 5 used a mixed methods design and 4 applied a qualitative study design. The methodologies used in those studies included case studies [27,30], qualitative descriptions [25,31], content analysis of open-ended questions in the survey [26,29,31,32], and secondary analysis of telephone interviews [33]. The data collection methods used in these studies included focus group interviews [27], semistructured interviews either via telephone or face-to-face [25,30,31], or surveys with open-ended questions [26,29,31,32].
Table 2. Characteristics of the included studies.

<table>
<thead>
<tr>
<th>Study, country</th>
<th>Study design</th>
<th>Program</th>
<th>Participants in the qualitative study</th>
<th>Method</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brennan et al [29], United States</td>
<td>Mixed methods</td>
<td>ComputerLink</td>
<td>Family caregivers of PwD (n=22)</td>
<td>Data collection: ● Messages posted on the discussion forum were collected ● Data analysis: ● Qualitative content analysis of collected messages</td>
<td>Pros: ● The forum and questions and answers section served as emotional support and social interaction opportunities for caregivers of PwD ● The public communication section allows participants to control the discussion focus and address the issue in a timely manner ● Self-paced learning provided more flexible learning for caregivers without time and space restraints</td>
</tr>
<tr>
<td>Duggleby et al [33], Canada</td>
<td>Secondary analysis of a mixed methods study</td>
<td>MT4Cb</td>
<td>Family caregivers of PwD (n=92)</td>
<td>Data collection: ● Telephone interviews ● Data analysis: ● Qualitative content analysis</td>
<td>Pros: ● Improved PwD’s self-efficacy</td>
</tr>
<tr>
<td>Fowler et al [30], United States</td>
<td>Case study</td>
<td>Virtual health care neighborhood technology</td>
<td>Family caregivers of PwD used the program (n=28)</td>
<td>Data collection: ● Interviews ● Data analysis: ● Qualitative descriptive</td>
<td>Pros: ● Provided social support and information sharing using the blog section. The blogs included safety, sleep issues, memory, social engagement, enjoyment, and suggestions. ● Participants have opportunities to interact with health professionals from different disciplines</td>
</tr>
<tr>
<td>Gaugler et al [26], United States</td>
<td>Mixed methods</td>
<td>CARES Dementia Care for Families</td>
<td>Family caregivers of PwD (n=41)</td>
<td>Data collection: ● Survey ● Data analysis: ● Qualitative content analysis of open-ended questions in the survey</td>
<td>Pros: ● Comprehensive content ● Use of real individuals with dementia in videos ● The video shows the stages/progression of dementia ● The flexibility of web-based delivery</td>
</tr>
<tr>
<td>Study, country</td>
<td>Study design</td>
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<td>Participants in the qualitative study</td>
<td>Method</td>
<td>Findings</td>
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<tr>
<td>Halbach et al [27], Norway</td>
<td>Qualitative case report</td>
<td>Mobile app mYouTime</td>
<td>Relatives and staff of PwD (n=17)</td>
<td>Data collection: - Focus group interviews - Data analysis: - Qualitative descriptive</td>
<td>Pros: - Well-structured learning units - Large font size - Contains videos - Contains basic and in-depth information</td>
</tr>
<tr>
<td>Hatink et al [28], the Netherlands</td>
<td>Mixed methods</td>
<td>The Digital Alzheimer Center</td>
<td>Family caregivers of PwD (n=6), PwD (n=6), and professional staff (n=6)</td>
<td>Data collection: - Observations - Web-based survey - Semistructured interviews</td>
<td>Pros: - Clear layout, calm background, large font, and contrasting color - Comprehensive and well-written information - Helped caregivers of PwD with understanding and dealing with dementia - Information can be accessed anytime and anywhere (flexibility in delivery)</td>
</tr>
<tr>
<td>Kovaleva et al [31], United States</td>
<td>Qualitative description</td>
<td>Tele-Savvy</td>
<td>Family caregivers of PwD (n=36)</td>
<td>Data collection: - Interviews</td>
<td>Data analysis: - Qualitative content analysis</td>
</tr>
<tr>
<td>Study, country</td>
<td>Study design</td>
<td>Program</td>
<td>Participants in the qualitative study</td>
<td>Method</td>
<td>Findings</td>
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<tr>
<td>Lewis et al [32], United States</td>
<td>Mixed methods</td>
<td>The internet-based Savvy Caregiver program</td>
<td>Family caregivers of PwD (n=47)</td>
<td>Data collection:</td>
<td>Data collection: Survey with open-ended questions Data analysis: Constant comparative analysis</td>
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<tr>
<td></td>
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<td></td>
<td>Pros: Provided opportunity for caregivers to connect with others via videoconferences (peer support and learning from others)</td>
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<td></td>
<td>The web-based program promoted access for those who need to travel Videoconferencing was facilitated by a health professional Contains prerecorded expert-delivered lessons Provided caregiver manual</td>
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<td></td>
<td>Cons: Information needs to be more relevant to stage-specific caregiving Need more videos to cover more complex situation and represents more diverse cultural backgrounds The program needs to be longer Videoconferences need to be longer Videoconferencing needs to be more engaging Technical issues (poor internet connection) Insufficient instructions on how to join videoconferences Need more detailed written and illustrated instructions for video viewing The web-based program may not be suitable for some people. The study only included people who have internet access</td>
</tr>
<tr>
<td>Ploeg et al [25], Canada</td>
<td>Qualitative</td>
<td>MT4C</td>
<td>Family caregivers of PwD (n=56)</td>
<td></td>
<td>Pros: Information and caregiving strategies were relevant and interesting to participants Videoclips of professionals, caregivers, and PwD The convenience of the internet program Presentation of the program</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cons: Spelling errors Technical difficulties (difficulty in navigating the website) Repetition of information Length of the program Did not provide an opportunity for participants to interact with other people Need a hard copy workbook</td>
</tr>
</tbody>
</table>
Participants in the qualitative study

- Data collection: 
  - Semistructured, open-ended, and telephone interviews
- Data analysis: 
  - Qualitative content analysis

Pros:
- Easy to navigate
- Provided the opportunity to reflect on and share their caregiving experiences
- Information was relevant and applicable to the individual caregiver’s situation
- Provided affirmation of their caregiving experiences through the content of the website and linked videos

Cons:
- MT4C did not apply to the caregiver’s current situation or suit their current needs because of their stage in the caregiving journey
- Technical issues and security concerns
- Writing or sharing their thoughts and experiences in MT4C
- Need a directory of services searchable by postal code
- Not having a person available to answer caregivers’ questions
- Not having a navigator to help the caregiver identify and access resources that meet their specific needs

Content of the Psychoeducation Programs

A total of 8 programs were reported in 9 studies (Table 3). In total, 2 studies reported the same program from different perspectives [25,33]. For example, Duggleby et al [33] only reported the reasons of nonusers in the web-based MT4C program, whereas Ploeg et al [25] reported users’ experiences in the same program. All programs were asynchronous web-based psychoeducation programs and had a clear indication of the educational component [25-33]. A total of 4 programs offered peer support functions [28-31]; of these 4 programs, 3 used asynchronous discussion forums or blogging [28-30] and 1 applied a synchronized method such as videoconferencing [31]. Health professionals’ involvement in the programs was reported in 4 studies [28-31]. Moreover, 1 study reported a program in a mobile app format, with limited details of psychoeducational content [27]. The duration of the psychoeducation programs ranged from 7 weeks [31], 2 months [28], 3 months [25,30,33] to 12 months [29]. Overall, 3 studies did not specify a time frame for participants to view or test the program [26,27,32].
Table 3. Details of the psychoeducation programs.

<table>
<thead>
<tr>
<th>Study</th>
<th>Program and duration</th>
<th>Delivery format</th>
<th>Program content</th>
</tr>
</thead>
</table>
| Brennan et al [29]     | ComputerLink; 12 months   | Asynchronized, web based      | • Content: dementia care information, decision support, and communication  
• Theoretical framework: multiattribute utility theory  
• Theoretical training: yes  
• Psychological training: unclear  
• Behavior training: unclear  
• Peer support: using private email and discussion forum  
• Facilitator: discussion forums were facilitated by health professionals. |
| Duggleby et al [33]    | My Tool 4 Care; 3 months  | Asynchronized, web based      | • Content: each web page contains frequently asked questions, resources, and a calendar. An electronic copy of the Alzheimer Society’s Alzheimer disease booklet was available.  
• Theoretical framework: Meleis’ theory of transition  
• Theoretical training: yes  
• Psychological training: yes  
• Behavior training: yes  
• Peer support: not offered  
• Facilitator: not offered |
| Fowler et al [30]      | Virtual Health Care Neighbourhood; 3 months | Asynchronized, web based      | • Content: information relevant to caring for people with dementia at home  
• Theoretical framework: not indicated  
• Theoretical training: yes  
• Psychological training: yes  
• Behavior training: yes  
• Peer support: using Question and Answer and Social Support forums  
• Facilitator: the blogging section was supported by health professionals. |
| Gaugler et al [26]     | The CARES for Families; the duration was not indicated | Asynchronized, web based      | • Content: information on understanding memory loss, living with dementia, and using the CARES Approach  
• Theoretical framework: not indicated  
• Theoretical training: yes  
• Psychological training: yes  
• Behavior training: yes  
• Peer support: not offered  
• Facilitator: not offered |
| Halbach et al [27]     | mYouTime mobile app; the duration was not indicated | Asynchronized, web based      | • Content: lectures, videos, and hyperlinks about dementia care. Details were not discussed in the paper.  
• Theoretical framework: not indicated  
• Theoretical training: unclear  
• Psychological training: unclear  
• Behavior training: unclear  
• Peer support: not offered  
• Facilitator: not offered |
| Hattink et al [28]     | The Digital Alzheimer Center; the duration was not indicated | Asynchronized, web based      | • Content: information about dementia, an overview of appointments, community sections, news, and upcoming events  
• Theoretical framework: not indicated  
• Theoretical training: yes  
• Psychological training: yes  
• Behavior training: yes  
• Peer support: using the forum  
• Facilitator: participants can privately email health professionals or make an appointment. |
Synthesized Findings

Overview

A total of 87 findings were extracted and grouped into 20 categories based on similarities and differences. These were further synthesized into five findings: (1) web-based learning as an empowering experience, (2) peer support, (3) satisfactory and unsatisfactory program content, (4) satisfactory and unsatisfactory technical design, and (5) challenges encountered in web-based learning (Multimedia Appendix 5). These synthesized findings are built on evidence rated as moderate to high confidence, which is outlined in the ConQual summary of findings in Multimedia Appendix 6. Multimedia Appendix 7 presents the meta-aggregation flowchart.

Synthesized Finding 1: Web-Based Learning as an Empowering Experience

This synthesized finding was based on 9 findings from 7 studies [26-32]. Caregivers who used web-based psychoeducation programs had a sense of empowerment through the knowledge they gained, and activities were undertaken [28-30]. For example, 1 participant stated the following [30]:

Being a part of the study at that time in my life really helped me cope with difficult family issues and decisions.

Caregivers welcomed topics on caregiver coping skills, which helped them develop strategies to deal with everyday challenges [29,32]. One participant stated the following [32]:

It is a gentle reference vehicle to understanding Alzheimer’s changes. It won’t smack you in the face with the fear of what is coming but will prepare you for techniques to cope.

Caregivers perceived that the knowledge they learned through real-life stories enabled them to understand the disease, which improved their self-efficacy [26-28]. One participant stated the following [26]:

The examples and the stories of families who live with Alzheimer’s were very informative and gave me comfort that I, too, can do this.

Some programs encouraged participants to complete their behavioral appraisal and develop a long-term plan [25]:

It [MT4C] made me even realize somebody else needs a list of doctors and [chuckles] you know, things like that... It made me think about personal care in the future because that’s long-term care.

Some caregivers were initially intimidated by web-based learning, but their experience in a well-run web-based classroom encouraged them to engage with the program [31]:

At first I was... this is not gonna work; I’m 60 years old. It really worked, I loved going to school online, I thought I was in a real class—I’m talking a real classroom.

Similarly, another participant indicated the following [30]:

I was a little intimidated with it at first but then I got on and it worked very smoothly, you know, the way it was supposed to and it made the experience kind of fun.

Participants expressed that having a program facilitator to answer their questions may further enhance their experience [25]. For example, 1 participant commented the following [25]:

Having a person available to answer caregivers’ questions by telephone and having a navigator to “be that bridge” to help the caregiver identify and access resources that meet their specific needs.

Overall, web-based psychoeducation programs empowered participants by enhancing their self-efficacy, skill building, knowledge sharing, and self-reflection, which contributed to a positive learning experience.

Synthesized Finding 2: Peer Support

This synthesized finding was based on 9 findings identified from 6 studies [25,28-32]. Peer interactions were important factors that influenced caregivers’ experiences in the web-based...
psychoeducation program. Asynchronized peer support included web-based forums for participants to exchange information and was perceived positively by participants [28-30]. One participant stated [29]:

> There are frequent statements of encouragement and support among caregivers for example “My husband is in the middle stages of the disease and I would like some suggestions on how to occupy his time...” “Dorothy I also have a problem with my wife who likes to walk and gets bored...” “Hi this is Sue. I noticed a reply to idle Time....”

Reading fellow caregivers’ stories provided an opportunity for caregivers to share, reflect on, and have a better understanding of dementia care. For example, 1 participant wrote the following [30]:

> Oh, I’m not out here alone, kind of thing but just to be able to see what other people’s stories were like, how others were handling things and seeing how people interacted with each other. That medium was really valuable.

Encouragement and support from synchronized online peer support groups were also considered helpful [31]. However, not all peer support was positive. Issues identified in synchronized online peer support groups were more apparent. Poor group interactions were reported in 1 study that used videoconferences and negatively influenced caregivers’ experience. Group members were not focused on the topic, and a lack of equal opportunity to contribute to the group meeting and a desire to have more interactions were reported [31].

When the program did not offer a peer support function, participants specifically commented on the value of connecting and sharing experiences with others [25,32]. For example, 1 participant commented the following [32]:

> I don’t have the option of sharing or interacting with others. The opportunity for questions related to my situation are not possible.

Caregivers also suggested the following [25]:

> Adding a feature to MT4C to enable caregivers to connect with one another to share information, experiences, and caregiving strategies would be helpful.

Caregivers perceived that a facilitator played a crucial role in motivating them and clarifying the issues discussed in peer support groups [31]:

> One of the very helpful parts of the chats was to have positive feedback from the teachers. I don’t think caregivers get very many “good job on that” comments. It is easy to know when we mess up... hard to know that we did it well.

Peer support during the program reduced caregivers’ feelings of isolation, and many participants expressed a desire to stay connected after the program ended [31]:

> For me it was a lifesaver... seeing all those people from all around the country... they are not really handling it any better than I ... I don’t feel so alone in spirit.

**Synthesized Finding 3: Satisfactory and Unsatisfactory Program Content**

This synthesized finding was based on a total of 17 findings identified from 7 studies [25-29,31,32]. The program content aspects considered in this finding include program components, such as video, and the information presented in the video or text format, such as different topics covering dementia caregiving strategies. No content was delivered in a synchronized format in the included studies.

A video component was welcomed by most participants, especially when a real person with dementia and their caregivers were featured in the video [32]. Videos enhanced caregivers’ understanding of dementia progression and care needs at different stages [26,27,31]. One caregiver stated [26]:

> I really liked the videos that showed the progression of the disease in the early, middle, and late stages of the disease. For example, the making coffee and taking a bath example. I also liked the driving example, too, about the different parts of the brain and how they are affected.

Other caregivers echoed similar comments [32]:

> Person with dementia was very interesting and I felt like I could connect with them.

The video structure and content also contributed to caregivers’ experiences. Although some programs’ videos were well structured [27], in other programs, the video display was too small [26], had poor audio quality [27], and content lacked cultural diversity [31]. Additional videos to highlight more challenging situations were requested by participants in 1 study [31]; for example:

> The Caucasian daughter (age 61) suggested the vignettes did not portray the “messiness of life”—times when a care recipient may not follow caregiver’s guidance, multiple family members involved in caregiving, and families with limited resources: I would have liked to see a daughter or son single caregiver with just a parent, try to make it more identifiable and inclusive.

Caregivers perceived that the information provided in the web-based psychoeducation program was important. They welcomed information that accommodated their individual learning needs [27,28,31]. One caregiver stated [32]:

> Good information, I found myself surprised at being able to relate to a lot of it.

Participants also perceived that the information provided should be relevant to the individual caregiver’s needs and their caregiving journeys [26] and detailed and practical [25]. One participant stated the following [25]:

> I feel like I’m not there yet; Mom’s still early, so some of the things are a bit more advanced...

They particularly liked the information presented by both caregivers and experts [32]. The participants also noted that...
some programs missed important topics [25, 27, 31]. One participant stated [27]:

*It was a known issue that the 23 lectures were not covering the entire area, and this was also remarked on with several participants mentioning missing topics and in-depth information.*

Most participants in this review were satisfied with the video content and written information included in web-based psychoeducation programs.

**Synthesized Finding 4: Satisfactory and Unsatisfactory Technical Design**

This synthesized finding came from a total of 23 findings identified from 6 studies [25-28, 31, 32]. The program design aspects considered in this finding include structure, language, functionality, accessibility, and supplementary material. Participants liked a clear page layout with a large font size for the content [27, 28, 32]. A lack of systematic layout was reported in 1 study [31]:

*Participants suggested that the [printed] manual be laid out more clearly (e.g., include a table of contents and a glossary) and be more precisely coordinated with the videos, videoconference “lectures,” and “homework” assignments.*

Participants identified grammar and spelling errors in 2 programs [27, 32]. There were also concerns about the literacy level of 1 program [25]:

*It is a lot of text and the literacy level. Oh, the other thing is it’s only in English... you need to make the language a bit simpler.*

One caregiver suggested that the case scenario presented needed to be positive to provide a better learning experience [26]:

*I found it very sad to be left with the vision of the dear man peeling bananas. You could have chosen something a bit more uplifting.*

Caregivers in 1 program considered quizzes to be the least helpful component [27]. Participants in another program experienced information overload and were frustrated by lengthy, repetitive, and missing content [32].

Caregivers especially welcomed the flexibility, convenience, and easy navigation of psychoeducation programs delivered on the web [28]:

*You can check this information anytime, even in the middle of the night.*

These features were extremely helpful for caregivers who lived far from the place where a face-to-face program might be delivered [31]:

*I live forty miles from everywhere; it was wonderful... It was good to be able to do it online rather than trying to get in the car, considering the traffic situation here.*

The caregivers expressed that the program website should have a bookmark function [32]. Supplementary materials, such as instruction manuals, were also suggested by the participants when they were not provided [31, 32]. Caregivers would also like ongoing access to the program after completion for various reasons [26, 30, 31]. One caregiver stated [31]:

*Caregivers could not access the videos after Tele-Savvy conclusion; however, many stated that they would be willing to rewatch videos, share them with family members, and rewatch them when their care recipient is in a later dementia stage.*

**Synthesized Finding 5: Challenges Encountered in Web-Based Learning**

This synthesized finding was based on a total of 7 findings identified from 4 studies [25, 28, 31, 33]. Technical issues such as problems with accessing and poor internet connection were a great challenge in using 2 web-based programs [31, 33], which did not differentiate between asynchronized programs (information accessing) and synchronized online peer support. One participant commented the following [33]:

*My internet connection at home is poor—I live in a rural area.*

Others experienced problems during synchronized videoconferencing; or example [31]:

*Problems during videoconferences (e.g., poor Internet connection, slow sound and video transmission, and insufficient instructions on joining videoconferences) affected connectedness.*

A low level of computer literacy among the participants also contributed to access difficulties [31, 33]. One participant commented the following [31]:

*Some caregivers noted that others struggled to follow some directions... and needed to be better aligned relative to their webcam and sit in a position with good lighting.*

Caregivers who struggled with the technology seem to prefer hard copy information [33]:

*Sometimes, you actually have to have something printed in front of you, uh, and I’m better off—I’m better with paper.*

Time was another challenge in this regard. Caregiving demands prevented some from participating in web-based psychoeducation programs [25, 28, 33]. One participant commented the following [33]:

*[I] work full-time early morning to late evening... and at the end of the day, I don’t have the energy or time to go on the computer.*

Similarly, another carer stated [25]:

*The more time I spend on the computer, the more [name of spouse] approaches me and saying “What are you doing? Why aren’t you sitting with me?”*

Other caregivers preferred learning through actual social contact [31]:

*It would have been better to absorb the content in a group setting, person to person... very difficult to have a personal connection with a computer screen.*
Discussion

Principal Findings

Our review revealed that the empowerment caregivers experienced from participating in a web-based psychoeducation program was built on knowledge sharing, individualized support from the program facilitator, and skill building to foster positive thoughts. This empowerment enables the active management of care activities. Our findings support previous studies that define empowerment for caregivers as a learning process that enables them to improve their coping capabilities by enhancing self-efficacy and self-determination, thereby creating more constructive relationships with the people surrounding them [35-37]. Self-efficacy is the belief that a person can complete tasks effectively when faced with stressors [38]. A positive outcome of self-efficacy is associated with cultivating positive thoughts and self-control [39]. According to the self-determination theory introduced by Ryan and Deci [40], people are motivated to learn to achieve their goals when they have a sense of self-control and self-efficacy and feel connected to other people. The carefully designed programs identified in our review reflect the development of these capabilities that empower caregivers in their caregiving role. Our finding on empowering learning is also in line with the study by Sakashashi and Fujita [36], in which empowering education programs for caregivers of people living with dementia included coping strategies, understanding the caregiver role, self-reflection, and quality information to enable the person to find autonomy and the capacity to take on the role.

We found that peer support through psychoeducation programs has a positive impact on caregivers’ experiences. Caring for people living with dementia is associated with social isolation because of demands from caregiving and dementia stigma [41]. Peer support provides caregivers with opportunities to communicate with others and share their experiences, which can potentially help them acquire new knowledge, build skills, develop resilience, and reduce caregiver burden [42-45]. The caregivers in this review valued peer support experiences, reflecting on the benefits they received. Research also shows that knowledge exchange through peer interactions can improve caregivers’ sense of self-efficacy [46] and reduce depressive symptoms [47]. In contrast, the absence of group learning and support may be associated with a low level of self-efficacy [48].

Our review revealed the caregivers’ preferences regarding the content of web-based psychoeducation programs. From our review, video components were preferred by caregivers as a means to facilitate a better understanding of the information presented. We found that caregivers were particularly touched by videos that portrayed real-life stories. The findings of our review also indicated that the relevance of information displayed in pictures and text influenced caregivers’ experiences. This finding could be explained in the context of human cognitive function in processing information, in which visual stimuli, such as pictures, text, and videos, during focused attention are useful for learners to attain new knowledge [49,50]. However, the cognitive learning process is based on the condition that the information, or learning content, is relevant to learners [49]. A study that explored caregivers’ information needs and information-seeking behaviors indicated that the most frequently requested information was general information on dementia, care provision, self-care, and how to use available services [51]. A caregiver’s decision to access information depends on the quality and trustworthiness of the source [52]. Caregivers in this review valued learning content that facilitated reflection on their role and promoted self-care. In addition, our review found that caregivers’ learning needs were influenced by the stages of their dementia journey. Caregivers requested that information should be tailored to accommodate their differences, thereby enhancing their learning experience while avoiding mismatches between information and learning content. The information included in web-based programs should be tailored to the individual’s situation and address the individual’s needs, while simultaneously preventing information overload.

In this review, we identified that the technical design of a web-based psychoeducation program is another factor that influences caregivers’ learning experiences. The visual layout, structure, language used, functionality, and accessibility of the web-based program were important to the caregivers. Caregiver expectations in these aspects of program design within this review can be explained by how people sense and perceive the information displayed in a web-based program. The first step in human cognitive functioning for information processing occurs via the sensory system (ie, visual and audio), which filters out irrelevant information, notes the information that is of interest and relevance via short-term memory, and then lays down long-term memories [53]. According to Vu et al [50], website design needs to consider the user’s cognitive and physical capabilities. For example, older people will see contents on the screen more easily when the program design avoids the use of blue or green colors from the short-wavelength end of the visual spectrum and increases the resolution of screen contents [50]. The caregivers’ feedback on the web-based psychoeducation program design noted in our review reflects these recommendations.

Our review also identified various challenges for caregivers when using web-based psychoeducation programs and learning on the web. These challenges included, but were not limited to, caregiving demands, especially for those in the workforce, technical issues, and program design. In contrast to previous studies, our review did not identify caregivers’ concerns about the privacy and confidentiality of their information [54,55]. We found that although caregivers, especially those living in remote areas, perceived web-based psychoeducation programs as flexible, caregiving demands precluded many working caregivers from participating. Previous studies have found that web-based programs can support working caregivers to achieve a balance between work and caregiver demands, supporting them through web-based peer interactions that save both time and money [55,56], but this does require an individual’s resolution. According to West and Hogan [57], regular support group attendance was associated with members’ perception of support from the group, subjective well-being, compromises they made, and care responsibilities. Moreover, according to our review, using a web-based program depends on an individual’s perception of how useful it is to address their needs.
Research has identified that working caregivers report lower carer confidence compared with nonworking caregivers, indicating the need for additional support to build their skills and confidence [58]. However, the educational support programs reviewed here do not necessarily reflect this. A flaw noted in this review was that most programs were not available after the completion of the study, despite participants wanting to revisit some of the information. A previous study suggested that program usefulness depended on whether the function and cost met individual needs [59]. These factors potentially influence caregivers' feelings about web-based programs' usefulness in the long term.

It is important to consider group dynamics if peer interactions are included in a program. Previous studies have focused more on the positive aspects of support groups, with negative experiences rarely discussed. A forum was convened in 1 study to ascertain barriers to successful web-based group meetings and made recommendations, for example, that groups be arranged according to the similarity of caregivers' experience, have clear meeting agendas, and consider participants' diversity [60]. Other studies showed that the positive impact of support groups depended on peer interactions and how well groups were organized [57,61]. The caregivers in our review expressed concerns about poor peer interaction, lack of discussion topics, and lack of equal opportunities to contribute during group meetings. This highlights the importance of a trained facilitator leading a caregiver support group.

As identified in multiple studies [55,60], technical difficulties accessing a program, such as a poor internet connection, challenge the use of web-based programs, as does an individual's confidence and computer skills [62,63]. In our review, most participants felt positive about web-based psychoeducation programs; but to meet a broader audience, programs must consider the caregiver population that may not be technically savvy.

**Recommendations**

High-quality and carefully designed web-based psychoeducation programs offer positive experiences to informal caregivers of people living with dementia. To meet broader caregiver education and support needs, program designers should consider the following recommendations (Multimedia Appendix 7). First, the learning content and information provided must be tailored to caregivers' learning needs. This can be achieved by encouraging caregivers to self-diagnose their learning needs and select relevant sections. Second, web-based psychoeducation programs should include components to facilitate social connectedness among caregivers so that they can share their experiences and help each other. Third, having program facilitators who are trained health or social care professionals is imperative for engaging caregivers in the program and providing individualized support. Fourth, programs should integrate multimodality teaching materials, such as text, videos, discussion boards, and supporting group meetings, to attract learners at the cognitive information processing level. Fifth, asynchronous web-based learning and teaching are recommended to accommodate a broader audience, especially working caregivers. Sixth, the program content should be developed based on an education needs analysis of caregivers. Program providers should conduct ongoing evaluations of the quality and relevance of the information presented to ensure caregivers' confidence in the program, thereby enhancing its utilization. Seventh, initial training and ongoing technical support for caregivers are required when implementing web-based psychoeducation programs. A program should be accompanied by hard copy instructions to support caregivers when technical issues arise. Finally, most psychoeducation research has focused on program effectiveness. Future research should also focus on informal caregivers' experiences of using web-based psychoeducation programs to increase utilization.

**Limitations**

The main strength of this review is the rigorous adherence to the JBI systematic review and meta-aggregation protocol to minimize bias during the process. However, this review has a few limitations. First, only 9 articles were included; this is an indicator that research evidence from qualitative studies is limited. Second, this review was based on database searches in 3 languages: English, Chinese, and Arabic. Therefore, a bias exists in the selection of studies. Despite the primary effort to review studies in Chinese and Arabic, the lack of diverse evidence from different contexts in non-English studies is apparent. The caregivers' experiences identified in this review may not be representative of a wider culturally and linguistically diverse population. Transferability to similar contexts in qualitative research needs to be confirmed by the reader.

**Conclusions**

This is the first comprehensive systematic review to synthesize qualitative studies on dementia caregivers' experiences in web-based psychoeducation programs in a global context. The findings contribute to new knowledge about caregivers' learning experiences, including interactions with peers, learning content, program technical design, and challenges encountered in web-based programs. The synthesized findings confirmed that multiple factors affected informal caregivers' experiences. The enabling factors most often mentioned included the programs' quality and relevancy, support received, relevance to individual caregivers' needs, flexibility in delivery, and ability to connect to other caregivers and program facilitators without time and space restrictions. The impeding factors included caregiving demands, poor program performance (eg, internet connection), and the inability to meet individual caregiver's needs (eg, their caring situation) or preferences (eg, for a paper-based program).
**Acknowledgments**

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**Conflicts of Interest**

None declared.

Multimedia Appendix 1

Keywords.

[DOCX File, 14 KB - aging_v6i1e47152_app1.docx]

Multimedia Appendix 2

Search strategies.

[DOCX File, 32 KB - aging_v6i1e47152_app2.docx]

Multimedia Appendix 3

Findings and illustrations.

[DOCX File, 41 KB - aging_v6i1e47152_app3.docx]

Multimedia Appendix 4

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 item checklist.

[DOCX File, 21 KB - aging_v6i1e47152_app4.docx]

Multimedia Appendix 5

Table results of metasynthesis.

[DOCX File, 19 KB - aging_v6i1e47152_app5.docx]

Multimedia Appendix 6

The ConQual summary of findings.

[DOCX File, 15 KB - aging_v6i1e47152_app6.docx]

Multimedia Appendix 7

The meta-aggregation flowchart.

[DOCX File, 24 KB - aging_v6i1e47152_app7.docx]

**References**


https://aging.jmir.org/2023/1/e47152


Abbreviations

JBI: Joanna Briggs Institute

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

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Older Adults’ Pain Outcomes After mHealth Interventions: Scoping Review

Marcia Shade1*, BS, PhD; Mariya Kovaleva1*, PhD; Kimberly Harp1, MLS; Aqueasha Martin-Hammond2, PhD

1College of Nursing, University of Nebraska Medical Center, Omaha, NE, United States
2Luddy School of Informatics, Computing, and Engineering, Indiana University-Purdue University, Indianapolis, IN, United States
*these authors contributed equally

Corresponding Author:
Marcia Shade, BS, PhD
College of Nursing
University of Nebraska Medical Center
985330 Nebraska Medical Center
Omaha, NE, 68198
United States
Phone: 1 402 559 6641
Email: marcia.shade@unmc.edu

Abstract

Background: Pain is prevalent and poorly managed in older adults. Although pain self-management strategies are helpful, adoption and access are limited; thus, technology provides an opportunity for intervention delivery. Mobile health (mHealth) is feasible to use in older adults; however, we have yet to understand the effect of mHealth pain self-management interventions on pain outcomes in older adults.

Objective: The purpose of this scoping review is to examine the characteristics of mHealth interventions and their efficacy on pain outcomes in older adults with musculoskeletal pain.

Methods: With the assistance of a medical librarian, keywords and subject headings were generated, including but not limited to mobile health application, mHealth, digital, pain, pain management, and older. A search was conducted for papers in journal databases, including PubMed, Embase, CINAHL, Scopus, and IEEE Xplore, between 2000 and 2022. Papers were screened according to predetermined inclusion and exclusion criteria, and reference lists were reviewed for additional paper inclusion. Three authors appraised the methodology of papers independently, then collaboratively to synthesize the evidence.

Results: Six publications were included in the scoping review. The design and methodology ranged widely from pilot studies to a comparative effectiveness trial. Older participants in the studies reported a variety of musculoskeletal conditions. Delivery of the mHealth pain self-management interventions incorporated mobile devices, such as a smartphone or tablet. Most mHealth-delivered interventions were multicomponent and incorporated elements of in-person and telephone access to an interventionist. The findings suggested mHealth interventions may reduce pain intensity; however, pain interference and other pain-related conditions did not have a statistically significant reduction.

Conclusions: Research that has explored mHealth for pain self-management is beginning to move beyond feasibility. The few experimental studies conducted in older adults are heterogeneous, and the interventions are mostly multicomponent. It is premature to conclude the interventions’ significant effect on pain or pain-related symptoms. As technology continues to integrate into health care, more experimental research is warranted to examine the efficacy of mHealth interventions on a variety of pain outcomes in older adults.

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KEYWORDS

mHealth; older adults; pain; self-management; pain management; mobile health; musculoskeletal pain; scoping review; pain outcomes; mobile phone
**Introduction**

The population of older adults in the United States is expected to reach 80.8 million by 2040. Along with the population increase, it is likely that the number of individuals with chronic conditions and symptoms, such as chronic pain, will grow [1]. The prevalence of pain in adults 65 years of age and older is higher than in the general adult population globally and in the United States [2].

The concept of “pain self-management” has not been well-defined in the literature. Some researchers have defined self-management as a behavior that helps patients maintain wellness through several tasks: condition management, creation of new meaningful behaviors, and emotion management [3]. Researchers have also postulated that the term “self-management” is often used interchangeably with terms such as “self-help,” “guided self-help,” “self-management strategies,” “self-management interventions,” “coping strategies,” and “self-care.” It remains unclear whether pain self-management presumes a collection of strategies for patients or packaged interventions and treatments [4]. Since pain self-management has not been consistently defined in the literature, this variation can influence studies exploring this concept.

Pain self-management has been historically encouraged among older adults with chronic pain [3,5]. For example, yoga, tai chi, qigong, massage, cognitive behavioral therapy, and music therapy are self-management interventions that have been reported to improve musculoskeletal pain in older adults [5-7]. To improve accessibility and adoption, pain self-management interventions have also been developed and delivered using technology. In fact, mobile health (mHealth) software apps are a modality that has gained popularity to promote pain self-management interventions [8-10].

While definitions of mHealth vary, it is often defined as the use of mobile phones, tablets, sensors, and other wireless devices to help accomplish health objectives [11,12]. mHealth software apps are typically task-specific, health-related computer programs that can be downloaded on the internet for use on a personal mobile device. Not only may mHealth apps track health and lifestyle [13], but these apps may also facilitate symptom and disease management among older adults [14]. In the pain realm, the function of mHealth may support an older adult’s remote pain monitoring and reporting, improve patient–health care provider communication, and promote therapeutic pain treatment delivery and pain research access [15].

The possibilities are numerous for mHealth and older adults who have pain. In total, 28% of older adults currently use at least one mHealth app, and 49% of those between the ages of 50 and 64 years were more likely to have used an app than 38% of older adults between 65 and 80 years of age [16]. Although there are usability barriers with devices that deliver mHealth, pain management via mHealth is feasible and acceptable for older adults [17]. Among older adults with minimal prior use of mHealth, most report willingness to try mHealth to help manage pain symptoms and pain medications. Older adults also appreciate the potential benefit of being able to contact their health care provider and safely manage their pain [18]. Given the acceptability and potential usefulness of mHealth pain self-management interventions for older adults, a review of the evidence is warranted. This scoping review was guided by the following research questions: What are the characteristics of the mHealth pain interventions that have been used in older adults? What effect do mHealth interventions have on pain outcomes in older adults?

**Methods**

**Study Design**

The aim of a scoping review is to conduct a broad analysis of available evidence to answer a research question [19] and demonstrate the range of evidence pertinent to the research question [20]. The methodology used in this review is based on the Arksey and O’Malley [19] framework. This scoping review involved five steps: (1) formulating the research questions, (2) identifying relevant studies, (3) study selection, (4) charting the data, and (5) collating, summarizing, and reporting the results [19,20].

**Search Strategy**

To obtain a comprehensive review of the literature, the research team performed a search across multiple bioscience and biomedical databases, including MEDLINE via PubMed, Embase, CINAHL, Scopus, and IEEE Xplore for pertinent papers. The results were limited to peer-reviewed papers published in English between 2000 and 2022. The search was performed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The search strategy, designed by an experienced academic medical librarian (KH), combined controlled vocabulary terms and free-text words on the concepts of mobile apps, pain management, and adults aged 60 years or older. The full search strategy is included in Multimedia Appendix 1. The systematic search was last run in September 2022. To minimize bias, the researchers used a broad search strategy to be inclusive across gender, sex, orientation, race, ethnicity, ability, literacy, socioeconomic status, and comorbidity. We solely focused on interventions for noncancer chronic pain among older adults. The search resulted in 1840 unique papers. The research team used the citation manager, RefWorks, to remove 4 duplicate papers. This resulted in 1838 unique papers. These papers were then screened and ascertained for relevance to the inclusion and exclusion criteria.

**Eligibility Criteria**

Studies were included in this review if they aimed to explore the outcomes of using mHealth pain interventions in older adults. Older adults were defined as those individuals 60 years of age or older as characterized by the World Health Organization [21]. Studies were included if the mean age of study participants was 60 years or older. We included intervention and cohort studies published in English. Studies were excluded if the pain intervention was delivered on a personal desktop computer (ie, nonmobile device) or if participants did not report musculoskeletal pain. Study protocols, opinion and editorial papers, reviews, case studies, abstracts,
position statements, dissertations and theses, guidelines, book chapters, conference proceedings, and solely qualitative studies were excluded. The flowchart [22] of the database search and screening process is shown in Figure 1. Papers were evaluated according to study methodology. 

**Figure 1.** Scoping review flowchart mHealth interventions for pain outcomes in older adults.

### Charting the Data

Three authors (MS, AMH, and MK) selected the final set of studies. Two authors (MS and MK) reviewed and organized the data that pertained to research questions. The data included country, median or mean age, sample size, race or ethnicity, clinical pain diagnoses or conditions that were the subject of treatment, devices used to deliver mHealth, mHealth intervention characteristics, and pain outcomes. Six papers were included, and the data are summarized in Multimedia Appendix 2 [23-47].

### Results

#### Overview

In total, 4 of the selected studies were conducted in the United States, 1 study was conducted in Sweden, and 1 in the United Kingdom. The study designs varied; 2 studies were randomized controlled trials [48,49]. Other designs included a mixed methods exploratory within-subject pre- and posttest study [50], longitudinal cohort study [51], a phased randomized wait list control trial [52], and a randomized noninferiority comparative effectiveness trial [53].

The papers included men and women (mean age range 63-70 years; 45%-91.7% White). Sample sizes of the studies ranged from 12 [50] to 499 participants [51]. The study participants’ clinical pain diagnoses included those commonly associated with chronic musculoskeletal pain. Pain and corresponding diagnoses included knee or hip pain from osteoarthritis [48,51], back pain [53], multiple pain locations [52], musculoskeletal and neurological pain [50], and chronic noncancer pain [49].
Devices Used for Intervention Delivery
In 3 studies, a smartphone or tablet were used to deliver a downloaded software app or stream content as an mHealth intervention [48,49,51]. Another study incorporated a wrist-worn activity monitor with a software app delivered using a smartphone or tablet [52]. One study incorporated an artificial intelligence engine that delivered the mHealth intervention using an interactive voice response via telephone [53]. One study used a virtual reality (VR) headset to deliver the mHealth intervention [50].

mHealth Pain Self-management Intervention Characteristics
Despite the similarity in using mHealth, the interventions varied widely in the structure, content, and duration. Overall, the structure of the intervention components varied. Interventions incorporated a mixture of mHealth along with in-person and access to other interventionalists such as a coach or therapist. An in-person component was present in one study [52]. By contrast, in another study [52], an initial phase of the intervention included group sessions led by interventionists. In 4 studies, telephone access to an interventionist was offered [48,49,51,53].

The studies also varied in content and duration. In 2 studies, exercise and osteoarthritis education were the main intervention components [48,51]. In the VR study, distraction was used for coping and relaxation as the main intervention component. Older adults played games or interacted for 15–45 minutes, with virtual activities focused on pet engagement, animals, music, and travel [50]. In one study, pain and coping skills training were used. The pain and coping skills training was web-based and included group videoconferencing led by expert facilitators. An app was used as part of the intervention to help tailor pain management goals for 12 weeks. Although it was in the first 3 weeks of the intervention, this was the only study with in-person groups [52]. One study included a multicomponent intervention to encourage behavioral activities for symptom monitoring. Behavioral activities included the daily entry of pain symptoms, diet, and behavior tracking. Older adults received weekly health telecoaching sessions with tailoring of lifestyle adjustments to manage pain symptoms [49]. One study used cognitive behavioral therapy delivered by artificial intelligence, and the intervention incorporated daily interactive voice feedback [53].

Pain and Pain-Related Outcomes
In each study, the intervention’s efficacy for decreasing pain intensity was measured. In 5 studies [48-51,53], pain intensity was measured using the numeric rating scale [23,27]. Fanning and colleagues [52] used the Patient-Reported Outcomes Measurement Information System (PROMIS) 3-item pain intensity scale [29]. In 2 studies where the numeric rating scale was used, pain intensity was measured within the past week [48,51]. In one study, current pain intensity was measured [49]. In 2 studies, a time-framed measure of the pain outcome was undefined [50,53]. In the study that used the PROMIS tool, pain intensity was measured in the previous week [52]. A decrease in pain intensity after the delivery of the mHealth interventions was reported in all studies.

Pain interference was measured in 2 studies. In one study [53], the items on the Brief Pain Inventory were used [44,45], and in another study [52], the PROMIS pain interference scale was used [29]. A statistically significant difference was not found in pain interference after the use of an mHealth intervention in one study [52]. In the other study [53], it was not reported whether pain interference had a statistically significant change after the mHealth intervention.

Additional pain-related outcomes were measured in the selected papers. Depressive symptoms were measured in 2 studies [50,53] and did not improve after the mHealth interventions. A nonsignificant decrease in anxiety and emotional affect was found in one study [49]. Similarly, in the 2 studies that measured quality of life, no change was found [49,50]. Pain-related disability was measured in 2 studies and did not demonstrate a statistically significant improvement after implementing mHealth interventions [49,53].

Discussion
Principal Findings
A scoping review was conducted to examine the characteristics of mHealth interventions and their efficacy on pain outcomes in older adults. Consistent with the purpose of a scoping review, we demonstrated the breadth of evidence on a topic [19]. The main findings of our review were (1) mHealth interventions varied widely in structure, content, duration, and target audience in terms of pain diagnoses; (2) there was a statistically significant reduction in pain intensity in all studies; and (3) varied results were attained regarding other pain-related outcomes, with no consensus possible, due to the small number of studies to date.

The number of studies that focus on measuring pain or pain-related outcomes in older adults is sparse. Most studies where mHealth for pain was explored were excluded due to participants having a mean age of less than 60 years old. The sample sizes of the studies varied, which may be attributed to usability barriers in the oldest old of adults, leading to challenges in recruiting older participants for mHealth pain intervention studies. Many excluded studies also focused on usability, acceptance, and design of mHealth pain interventions, and yet while important for aiding adoption, many of these studies did not measure an effect on pain outcomes.

There were a variety of devices used to deliver mHealth interventions, including smartphones or tablets. The use of smartphones would be the most logical device to deliver mHealth interventions due to the availability and increased use by older adults. Despite the common assumption that older adults do not use technology, many have adopted mobile devices, which is consistent with Pew research describing older adult’s use of smartphones has grown [54]. VR is gaining momentum for use in treatment and intervention delivery. VR has not routinely been included in mHealth interventions; however, a wireless VR headset (with or without a smartphone) may be transformed for a therapeutic treatment by virtue of the intended use of the software it is running [55]. Thus, VR was included in this review based on the definition of mHealth used...
in this scoping review and to explore the broad range of evidence. Although VR was used in one study [50], most of the literature on VR is focused on factors related to attitudes and usability in older adults [56,57], as opposed to the effect on pain outcomes. Other emerging devices, such as smart speakers (eg, Amazon Alexa and Google Home) and wearables (eg, Apple Watch and Fitbit), have yet to be widely explored for the delivery of mHealth pain interventions.

Most pain self-management strategies incorporate content elements of pain education, training or coaching to strengthen relaxation skills, coping, problem-solving, and communication [5]. In this review, the mHealth pain interventions varied and combined multiple approaches to affect older adults’ pain. The structure of the interventions varied, with most interventions incorporating access to in-person [52] or telephone or chat [48,49,51,53] interventionist. One perspective on this incorporation of a human component to mHealth interventions is that older adults may be unable or unwilling to partake in mHealth interventions remotely without access to an interventionist. It may be necessary to include interventionist access to help ease anxiety, assist older adults, or ensure proper intervention delivery. It is also fair to propose that mHealth delivery can be used to complement in-person care or support traditional interventions (eg, offer mHealth intervention between traditional in-person physician’s appointments). The characteristics of the interventions discussed in the studies are consistent with the evidence associated with pain management strategies that need to be promoted in older adults. A multimodal approach to pain is encouraged to manage pain in older adults, and what works for one person may not work for someone else. Although it is unclear from the review, mHealth interventions may need to incorporate a variety of strategies for tailoring and tangible support for older adults.

Pain is a biopsychosocial symptom, and several instruments were used to assess pain outcomes. Pain intensity was a universal outcome, but measurement occurred at different time points. For example, it is not clear if mHealth interventions affect the older adult’s current pain intensity or pain that occurred within the past week. Surprisingly, pain interference was only measured in 2 studies [52,53] and did not improve. Pain interference is defined as the degree to which pain prevents an individual’s participation in physical, cognitive, emotional, sleep, recreational activities, and experiencing enjoyment [58]. Contingent on the evidence presented in this review, even if pain intensity decreases, pain may continue to interfere with aspects of the older adult’s life. Therefore, a reduction in pain intensity may not capture an outcome that is meaningful to patients, particularly if pain continues to hinder activities. Self-reported pain interference needs to be measured in future studies using mHealth interventions for pain in older adults. Also, based on the heterogeneity and small number of studies in this review, it is unclear whether incorporating mHealth pain interventions significantly affects pain-related conditions, such as mental and emotional symptoms and disability. Future studies need to measure the biopsychosocial elements of pain and consistently use validated and reliable instruments to give direction and support for interventions.

More experimental studies are needed with large and culturally diverse samples to examine the efficacy of mHealth pain interventions on pain outcomes. Recruitment strategies must be such that older adults will be assured that training and assistance with technology will be provided to help alleviate apprehensions associated with usability. One example of assistance would be “navigators” that help older adults become acclimated with and troubleshoot the technology [59,60]. It is important to continue examining the role and outcomes of mHealth interventions for pain management in older adults. With the growing adoption of mobile devices, older adults have greater opportunities to use mHealth for pain management as a nonpharmacologic strategy, which may improve health outcomes and quality of life. Additionally, pragmatic issues of mHealth use among older adults such as cost and internet access may be examined.

**Limitations**

There are some limitations in this scoping review. The search identified few papers that focused on mHealth interventions for pain in older adults. As this is a rapidly growing body of research, other relevant papers could have been missed. For example, we did not include conference proceedings or abstracts from human-computer interaction databases, which may include additional experiments of mHealth pain interventions in older adults. The mental and behavioral health database, PsycInfo, was eliminated during the medical librarian’s preliminary search due to zero returns on the search terms combining keywords and controlled vocabulary for the concepts of mobile apps and chronic pain. Publication bias may have also caused us to miss papers with a negative or poor pain outcomes associated with mHealth interventions. Additionally, we only selected papers published in English.

**Conclusions**

This scoping review was conducted to examine the characteristics of mHealth interventions and pain outcomes in older adults. Although the research is beginning to move beyond usability and acceptance, few experimental studies have been conducted in older adults that focus on improving pain outcomes. The studies that have been conducted vary in design, sample size and diversity, measured outcomes, and interventional approach. As technology continues to integrate into health care, more research is warranted to examine the efficacy of mHealth interventions on pain outcomes in older adults.

**Conflicts of Interest**

None declared.

**Multimedia Appendix 1**

https://aging.jmir.org/2023/1/e46976
Search strategy.
[DOCX File, 23 KB - aging_v6i1e46976_app1.docx]

Multimedia Appendix 2
Mobile health intervention characteristics and outcomes.
[DOCX File, 22 KB - aging_v6i1e46976_app2.docx]

References
11. mHealth: new horizons for health through mobile technologies. World Health Organization. URL: https://apps.who.int/iris/bitstream/handle/10665/44607/9789241564250_eng.pdf;jsessionid=2BC00267D6D41A3E95FF7A92FE55D44?sequence=1 [accessed 2023-03-03]
21. Ageing. World Health Organization. URL: https://www.who.int/health-topics/ageing#tab=tab_1 [accessed 2023-03-03]


29. PROMIS. HealthMeasures. URL: https://www.healthmeasures.net/explore-measurement-systems/promis [accessed 2023-03-03]


40. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med 2001;16(9):606-613 [FREE Full text] [Medline: 11556941]

Abbreviations

mHealth: mobile health  
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses  
PROMIS: Patient-Reported Outcomes Measurement Information System  
VR: virtual reality
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Usability and Acceptability of Clinical Dashboards in Aged Care: Systematic Review

Joyce Siette1,2, PhD; Laura Dodds2, MPH; Fariba Sharifi2, MPH; Amy Nguyen2,3, PhD; Melissa Baysari4, PhD; Karla Seaman2, PhD; Magdalena Raban2, PhD; Nasir Wabe2, PhD; Johanna Westbrook2, PhD

1The MARCS Institute for Brain, Behaviour and Development, Western Sydney University, Westmead, Australia
2Australian Institute of Health Innovation, Macquarie University, Macquarie Park, Australia
3St Vincent's Clinical School, University of New South Wales, Sydney, Australia
4Biomedical Informatics and Digital Health, School of Medical Sciences, Charles Perkins Centre, University of Sydney, Sydney, Australia

Corresponding Author:
Joyce Siette, PhD
The MARCS Institute for Brain, Behaviour and Development
Western Sydney University
Level 6, Westmead Innovation Quarter, 160 Hawkesbury Rd
Westmead, 2145
Australia
Phone: 61 2 9772 6648
Email: joyce.siette@westernsydney.edu.au

Abstract

Background: The use of clinical dashboards in aged care systems to support performance review and improve outcomes for older adults receiving care is increasing.

Objective: Our aim was to explore evidence from studies of the acceptability and usability of clinical dashboards including their visual features and functionalities in aged care settings.

Methods: A systematic review was conducted using 5 databases (MEDLINE, Embase, PsycINFO, Cochrane Library, and CINAHL) from inception to April 2022. Studies were included in the review if they were conducted in aged care environments (home-based community care, retirement villages, and long-term care) and reported a usability or acceptability evaluation of a clinical dashboard for use in aged care environments, including specific dashboard visual features (eg, a qualitative summary of individual user experience or metrics from a usability scale). Two researchers independently reviewed the articles and extracted the data. Data synthesis was performed via narrative review, and the risk of bias was measured using the Mixed Methods Appraisal Tool.

Results: In total, 14 articles reporting on 12 dashboards were included. The quality of the articles varied. There was considerable heterogeneity in implementation setting (home care 8/14, 57%), dashboard user groups (health professionals 9/14, 64%), and sample size (range 3-292). Dashboard features included a visual representation of information (eg, medical condition prevalence), analytic capability (eg, predictive), and others (eg, stakeholder communication). Dashboard usability was mixed (4 dashboards rated as high), and dashboard acceptability was high for 9 dashboards. Most users considered dashboards to be informative, relevant, and functional, highlighting the use and intention of using this resource in the future. Dashboards that had the presence of one or more of these features (bar charts, radio buttons, checkboxes or other symbols, interactive displays, and reporting capabilities) were found to be highly acceptable.

Conclusions: A comprehensive summary of clinical dashboards used in aged care is provided to inform future dashboard development, testing, and implementation. Further research is required to optimize visualization features, usability, and acceptability of dashboards in aged care.

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KEYWORDS

dashboard; visualization; usability; acceptability; user interface design; health information technology; aged care; clinical; database; development; aged care

https://aging.jmir.org/2023/1/e42274
Introduction

Health information technologies are increasingly being used in the health care sector, including in aged care, due to their capacity to improve workflow efficiencies and quality of care [1,2]. A technology rapidly gaining momentum in health is electronic clinical dashboards. These typically provide a summary of vital clinical data relating to individual patients to increase users’ understanding of their health care needs and care, display trends in patient-reported clinical outcomes, and support decision-making [3,4]. Limited examples of clinical dashboards currently exist within aged care [5,6].

Aged care has a diverse workforce with varying levels of health and digital literacy. In order to address the needs of older adults (defined as individuals aged 65 years and older) in care, their families, and the workforce, dashboards ideally should be designed to support the perspectives and requirements of all relevant stakeholders in aged care. However, there is limited research on how best to present data to support the interpretation of resident outcomes [7]. Furthermore, while the use of visual information can help reduce information overload and improve understanding of data for users in general [4], it is unclear how different types of visual displays used in dashboards may affect comprehension and decision-making for aged care users.

It has been shown that the way in which information is presented (eg, icon displays vs tables, pie charts, and bar graphs) can impact the accuracy of decisions taken by health professionals [4], but limited work has examined whether interpretation of the visual information is dependent upon the expertise, knowledge, and experience of various dashboard users. Aged care organizations are being encouraged to adopt dashboards to improve the quality of care and resident safety [8]; however, dashboards can be used to communicate information to different users, including patients, clinicians, or others.

The aim of this review was to thus identify the visual features of clinical dashboards that are usable and acceptable to the varied number of users in aged care settings in order to help guide future development, design, and implementation of dashboards in aged care.

Methods

Search Strategy

Adhering to recommended procedures for systematic reviews (ie, PRISMA [Preferred Reporting Items for Systematic Reviews and Meta-Analyses] guidelines) [9], we conducted a literature search for peer-reviewed empirical studies until April 27, 2022, using a predefined search strategy in the following databases: MEDLINE, Embase, Scopus, PsycINFO, and CINAHL. Primary search terms were dashboard, aged population, aged care, acceptability, and usability; papers were limited to 2000 to April 2022, human subjects, and in English (see search strategy in Table S1 in Multimedia Appendix 1). To increase the comprehensiveness of the search, we scanned the reference lists and cited documents of included peer-reviewed articles (ie, snowballing) to identify any relevant articles missed by the searches.

Inclusion and Exclusion Criteria

We included peer-reviewed primary studies reporting a usability or acceptability evaluation of a clinical dashboard for use in aged care environments, including home-based community care, retirement villages, and long-term care (Table S2 in Multimedia Appendix 1). All study designs were included.

Study Selection

All potential studies were exported into a reference citation manager and duplicates were removed. The primary author (JS) removed additional duplicates. A random selection of 10% of the abstracts (n=200) was then screened by the 2 authors (JS and FS). An interreviewer agreement was high (100%), with no disagreement on which papers should proceed to full-text screening. FS conducted the remainder of the abstract review. Full-text articles were then obtained for screening by JS and FS, with AN moderating the final list of articles. Please see PRISMA diagram for a detailed summary (Figure 1).
**Data Extraction**

**Overview**

Data extraction was completed independently by 2 reviewers (JS and LD) and checked by an additional reviewer (AN). The data extraction tool was piloted to ensure complete documentation of the qualitative and quantitative components of the included studies. Once finalized, data were extracted on study general characteristics (eg, year, country, type of dashboards, participants, and study design), sample characteristics (eg, age and gender), dashboard visual features (eg, charts), acceptability and usability ratings, study findings, and recommendations.

**Acceptability**

Acceptability was defined as the users’ judgement on the appropriateness of the dashboard and its design features, which included sensitivity to their needs as well as usage levels and utility [10]. Adopting the theoretical framework of acceptability [11], perceived user acceptability was explored for the overall dashboard as well as specific design features as described by the study (eg, bar charts). Detailed examples of acceptability scoring are shown in Table 1.

Briefly, acceptability was categorized according to technology acceptability statements in validated technology usability tools or through other in-house developed surveys that were focused on users’ responses to acceptability. For example, statements such as “I found the system unnecessarily complex” in the System Usability Scale [12]; “I think the visual perception of the dashboard is rich” in the Quesionnaire for User Interaction Satisfaction [13-15]; and “Using this dashboard would enable me to accomplish tasks more quickly” in the Technology Acceptance Model (TAM) [16] were used to rate acceptability of the dashboards or its features. Acceptability was scored according to the confirmed metrics of these tools and were classified as low, medium, or high, for each scale. For example, with the TAM model, acceptability was defined as low (<50% agreement), medium (50%-70% agreement), and high (>70% agreement) [16].

In-house surveys typically used a 5-point Likert scale of agreement (1=highly disagree to 5=highly agree) to specific statements on the usefulness of the dashboard, its value, and its necessity (eg, Lee and Huebner [17]) and was scored as low (1-2), medium (2-4), and high (4-5) acceptability.

For qualitative articles, general and specific dashboard features that were perceived positively by all stakeholders in a single study were coded as high acceptability, features that included a mix of both positive and negative stakeholder feedback were coded as medium acceptability, and features that were perceived to provide minimal to no added value for stakeholders (eg, low staff engagement [18] or required significant improvements [19]) were categorized as having low acceptability.

![PRISMA diagram](https://aging.jmir.org/2023/1/e42274)
### Table 1. Scoring system for acceptability and usability of articles.

<table>
<thead>
<tr>
<th>Study design and measurement</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acceptability</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantitativea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Questionnaire for User Interaction Satisfaction [15]</td>
<td>&lt;5</td>
<td>5-7</td>
<td>&gt;7+</td>
</tr>
<tr>
<td>Technology Acceptance Model [16]</td>
<td>&lt;50% agreement</td>
<td>50%-70% agreement</td>
<td>&gt;70% agreement</td>
</tr>
<tr>
<td>In-house survey on the overall dashboard (eg, “the anticoagulation dashboard is necessary for high-quality home health patient care” [17]) and specific dashboard features (eg, “The graph combining edema status and weight is useful [17]”)</td>
<td>&lt;50% agreement</td>
<td>50%-70% agreement</td>
<td>70%-100% agreement</td>
</tr>
<tr>
<td>Qualitative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participant feedback</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative appraisals (eg, “The tablet is extra work, and for people with dementia, it’s very important for me to give them extra time.” [19])</td>
<td>Containing a mix of both negative and positive comments (eg, “On the right track but not quite there.” [20]; “Whether the system really works remains to be seen. At least it is [better] than nothing.” [21])</td>
<td>• Positive appraisal for overall dashboard use (eg, “I find this to be a very helpful tool in a team approach working together with the physician and other team members for the best possible outcomes for our patients” [17])</td>
<td>• Positive appraisal for specific dashboard feature (eg, “I have just received one alert, a yellow one, I contacted the older adult the day after...she was happy that it works, and it really works.” [22])</td>
</tr>
</tbody>
</table>

| Usability                     |     |        |      |
| Quantitative                 |     |        |      |
| System Usability Scale [12]  | <50 (low) | 50-70 (medium) | 70+ (high) |
| Technology Acceptance Model [16] | <50% agreement | 50%-70% agreement | >70% agreement |
| In-house survey (eg, “The CHF dashboard provides the ease of reviewing necessary patient information at one time.” [17]) | <50% agreement | 50%-70% agreement | 80%-100% agreement |
| Qualitative                  |     |        |      |
| Participant feedback         |     |        |      |
| Negative appraisals (eg, “there are no options that we might like to have clicked, that the clients are, for example, chronically or acutely confused.” [19]; “The staff struggled with the challenge of responding to acute events versus detecting trends and patterns of behavioural decline and determining how to integrate such monitoring into their daily schedules” [18]) | Mix of appraisals (eg, “We had difficulty logging into the system in the beginning.” [18]; “The system has a learning curve, so training is necessary” but “we can identify fixable usability challenges using scenario based training” [23]) | Positive appraisals (eg, “Oh, I love it. I have a sense of being cared for!” [21]; “The electronic form flows nicely. It is set up just like the paper form, is easy to follow and is one less thing on my desk.” [23]) |

*a*Acceptability subscores of the quantitative scales were used to compute the overall acceptability of the dashboards.
Usability

Usability was defined as the extent to which the dashboard could be used by the specified users to achieve their goals effectively, efficiently, and with satisfaction [24,25]. Usability was also rated for overall dashboard use and specific dashboard features using previously described methods focused on usability items in the tools (eg, System Usability Scale, Questionnaire for User Interaction Satisfaction, and TAM) for assessing low, medium, and high usability (eg, Dowding et al [26], Lanzarone et al [27]). These items typically focused on the dashboard’s effectiveness (ie, can stakeholders achieve their goals) and efficiency (ie, amount of effort and resources required to achieve their goal) metrics. For further information, refer to our scoring system described in Table 1.

Data Synthesis

Qualitative Data

For qualitative studies, acceptability and usability were synthesized using a thematic analysis [28] where main themes regarding the acceptability or usability of the dashboard (including its individual visual features) were first identified independently by JS and LD. Any discrepancies that arose were solved through discussion with the third member of the review team (AN). Themes were reviewed and amended by the review team and were subsequently organized into overarching topics for clarity and conciseness. A similar process was also adopted identifying the recommendations to improve acceptability and usability. Where possible, synthesis made according to different dashboard user types (eg, resident, caregiver, health care professional).

Quantitative Data

A narrative synthesis of quantitative articles was used to specify whether clinical dashboards and their features were considered acceptable and usable. Interreviewer disagreement on data extracted was resolved through discussion among the research team. The review team included academics with backgrounds in psychology (JS), aged care (LD and KS), public health (FS and MR), epidemiology (JW, MR, and KS), digital health (JW, AN, MR, and MB), pharmacy (KS, MR, and NW), human factors (MB), and data science (NW). The results were synthesized as a narrative review.

Quality Assessment

Study quality was assessed using the Mixed Methods Appraisal Tool (MMAT) [29] by three authors (JS, KS, and MR). This tool allows the appraisal of the methodological quality of 5 categories of studies: qualitative research, randomized controlled trials, nonrandomized studies, quantitative descriptive studies, and mixed methods studies. Each study category has 5 assessment criteria, which are scored as either “yes—criterion met,” “no—criterion not met,” or “unclear/can’t tell whether criterion met” [29]. Mixed methods studies are assessed against the relevant study categories, as well as the mixed methods studies category.

Two reviewers independently scored each study, and disagreements were discussed with a third reviewer to come to a consensus on the rating. An overall quality score was assigned to each study following the method described by MMAT [29]. The score was the overall percent of quality criteria met for an individual study. For multimethod studies, the overall quality score was the score for the lowest-scoring component.

Results

Overview

After excluding duplicates, our search strategy identified 2575 potentially relevant articles (Figure 1). After excluding articles that did not meet our inclusion criteria, a total of 14 peer-reviewed articles were included, although 2 articles were reported on the same dashboard [26,30,31] and were described collectively. Articles were most frequently excluded because they did not report an evaluation of a clinical dashboard.

Study Quality Assessment

The quality of studies ranged from 20% (n=3) to 100% (n=6) on the MMAT checklist (Table S3 in Multimedia Appendix 1) [18-20,22,23,26,27,30-35]. Although more than half of the studies (n=8) received scores greater than 60%, over a third of the studies (n=5) had scores less than 40%, indicating a mix of low, moderate, and excellent quality.

Characteristics of Studies

Study characteristics are summarized in Table 2. Studies were conducted mostly in the United States (6/12) [17,18,20,23,26,30-32], with 1 study conducted in Australia [33], China [34], Sweden [22], Italy [27], Canada [35], and Europe [19]. The majority of studies adopted a mixed methods design (8/12) [17,18,22,23,26,27,30,35], followed by a quantitative approach (3/12) [20,31,32] and 2 used a qualitative design [19,33]. Studies were carried out mostly in a home care setting (6/12) [17,18,20,22,26,27,30,31], which encompasses domiciliary care, community care, or other social care provided within the home in which the older adult is living or long-term care (6/12) [19,23,32-35], which refers to individuals in residential aged care, nursing homes, or other care facilities that provide permanent accommodation for persons who require consistent and ongoing services to assist with activities of daily living. Studies had varied sample sizes of users (median 32, range 3-292 [22,30]). Most studies described the experiences of health professionals including nurses (9/12) [17,22,23,26,30-35], aged care staff (5/12) [18,19,27,33,35], physicians (3/12) [20,32,35], with 5 studies including a mix of older adults in home or community care, respite care, and long-term care; staff; and health care professionals [18,22,27,32,35].

A summary of the methodological frameworks and theories used to develop or evaluate the dashboards is provided in Table S4 in Multimedia Appendix 1 [16,17,30,32,35-46]. Most dashboards (8/12) used a developmental framework [17,20,22,23,26,27,30,34,35], including feedback intervention theory [47], and most also used an evaluation framework (7/12) [19,22,23,26,27,30,34,35], with the most common being the TAM [16] and the UK’s Medical Research Council complex intervention evaluation framework [48].

https://aging.jmir.org/2023/1/e42274

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(page number not for citation purposes)
<table>
<thead>
<tr>
<th>Author (year), country (year), country</th>
<th>Study design</th>
<th>Platform</th>
<th>Software used</th>
<th>Focus</th>
<th>Study setting</th>
<th>System users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algilani et al [22] (2016), Sweden</td>
<td>Clinical</td>
<td>In-house</td>
<td>Health status</td>
<td>✓</td>
<td></td>
<td>Older adults: 87.6 (—) 60</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nurses: 3 — 100</td>
</tr>
<tr>
<td>Bail et al [33] (2022), Australia</td>
<td>Qual</td>
<td>Humanetix</td>
<td>Administrative, health status</td>
<td>✓</td>
<td></td>
<td>Staff: 65 — —</td>
</tr>
<tr>
<td>Bell et al [32] (2020), USA</td>
<td>Quant</td>
<td>Unclear</td>
<td>Medication and prescribing practices</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Older adults: 112 — 0</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Physicians: 6 — —</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nurse: 1 — —</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nurses: 18 — 100</td>
</tr>
<tr>
<td>Cui et al [34] (2018), China</td>
<td>Quant</td>
<td>Mobile app</td>
<td>Unclear</td>
<td>Administrative, health status</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dowding et al [30] (2018), USA</td>
<td>Quant</td>
<td>Paper-based</td>
<td>In-house</td>
<td>Administrative, health status</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Dowding et al [31] (2018), USA</td>
<td>MM</td>
<td>Computer</td>
<td>Morae software (Tech-smith)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dowding et al [26] (2019), USA</td>
<td>MM</td>
<td>Web-based</td>
<td>Morae software (Tech-smith)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kramer et al [20] (2016), USA</td>
<td>Quant</td>
<td>Computer</td>
<td>In-house</td>
<td>Medication and prescribing practices</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Lanzarone et al [27] (2017), Italy</td>
<td>Administrative</td>
<td>Diamond-Touch table</td>
<td>Geodan</td>
<td>Administrative</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Lee and Huebner [17] (2017), USA</td>
<td>MM</td>
<td>Computer</td>
<td>MS Excel</td>
<td>Administrative, health status</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Mei et al [23] (2013), USA</td>
<td>MM</td>
<td>Computer</td>
<td>MS InfoPath, Sharepoint</td>
<td>Adverse events</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Papaioannou et al [35] (2010), Canada</td>
<td>MM</td>
<td>Web-based</td>
<td>In-house</td>
<td>Medication and prescribing practices</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Note: Sample size, n; Age (years), mean (SD); Sex (female), %
An overview of dashboard type and purpose are shown in Table 3. Dashboards were either already established in existing information systems (8/12) [18,19,22,23,27,32,33,35] or were prototypes (4/12) [17,20,26,30,31,34]. Most dashboards were accessed through a computer (5/12) [17,19,20,23,26] or specialized hardware (eg, DiamondTouch table [27]) or a web-based platform (4/12) [18,26,32,35] (Table 2).

The main purpose of dashboards was grouped into four categories: (1) health status (8/12) [17,19,22,26,30,31,33,34], which included monitoring of vital signs, physiological, and functional status such as weight and blood pressure; (2) medication and prescribing practices (3/12) [20,32,35], which referred to medication discrepancies and appropriate prescribing practices; (3) administrative (7/12) [17-19,27,31,33,34], which included exploring and viewing older adult care pathways as well as changes to services or care that the older adult is receiving; and (4) adverse events (1/11) [23], which refers to the specific incidence of falls or other behavior-related events.

Dashboard features are described in Table 3 and were broadly categorized into information, analytic capability, and other functionalities. Most information depicted on dashboards included health conditions prevalence and incidence (9/12) [18,19,22,23,26,30-33] and medication use patterns (6/12) [17,18,20,32,33,35], which could be displayed over time (8/12) [17,18,22,26,27,30,32,33]. Other information included geographical location (2/12) [18,27], hospitalization data (2/12) [18,31], and linkage to additional resources of complementary information and guidelines (2/12) [27,32].

**Analytic capability** referred to the dashboard’s ability to display data in a meaningful way (eg, wound record, medical status, and medication administration and use) either through descriptive analysis (12/12) [17-20,22,23,26,27,30-32,34,35], predictive ability (7/12) [17,18,22,26,30,32,35], or prescriptive capability (7/12) [17,18,26,30,32,33,35] (ie, predicting what action should be completed according to available guidelines),
which was supported by a visual exploration of the data through charts or other graphical means (6/12) [17,18,20,26,30,31].

*Other functionalities* included interactive forms dedicated to client assessment and service planning (11/12) [17,19,20,22,23,26,27,30,32-35], which included initial assessments, transitions in client care, client-level monitoring (eg, vital signs), as well as the management and coordination of aged care service operations to suit clients’ needs. The ability for stakeholders to communicate and interact was also described (6/12) [17,18,20,23,27,32].
Table 3. Summary of dashboard features and functionalities including visual application and analytic capabilities.

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Visual representation of information</th>
<th>Analytic capability</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>General Prevalence/incidence**&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Specific Descriptive Predictive&lt;sup&gt;b&lt;/sup&gt; Prescriptive&lt;sup&gt;c&lt;/sup&gt; Visual exploration&lt;sup&gt;d&lt;/sup&gt; Epidemiologic monitoring or surveillance</td>
<td>Client assessment and service planning&lt;sup&gt;e&lt;/sup&gt; Stakeholder communication and interaction&lt;sup&gt;f&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Spatio&lt;sup&gt;h&lt;/sup&gt; Resources&lt;sup&gt;i&lt;/sup&gt;</td>
<td>Events over time&lt;sup&gt;j&lt;/sup&gt; Medication use patterns Hospitalization</td>
<td></td>
</tr>
<tr>
<td>Algilani et al [22] (2016)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Bail et al [33] (2022)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Bell et al [32] (2020)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cui et al [34] (2018)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dowding et al [31] (2018)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dowding et al [26] (2019)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lanzarone et al [27] (2017)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mei et al [23] (2013)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shiells et al [19] (2020)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Wild et al [18] (2021)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**a**Refers to dashboard/application capability of predicting what could happen (eg, dashboard triggers alerts on older adults with high risk based on risk assessment modeling of older adult health concerns).

**b**Refers to dashboard/application capability of recommending what should be done according to guidelines (eg, decision support).

**c**Refers to any graphical representation of data (eg, charts, graphs, and maps).

**d**Includes initial assessment and transitions in older adult care, monitoring (eg, vital signs), and the management and coordination of aged care service operations to suit older adult needs.

**e**Includes capability of communicating between users of the dashboard and data sharing.

**f**Refers to whether the dashboard/tool provided prevalence or incidence data or indicated the potential to compute these data for reporting purposes.

https://aging.jmir.org/2023/1/e42274
Refers to visual applications that directly or indirectly provide geographical area or location (e.g., staff and clients).

Refers to whether the dashboard/application provided links to additional physical resources or complementary information, guidelines, and recommendations outside that of the information within the dashboard/application (e.g., through links to external websites/files).

Refers to whether the dashboard/application had the capability to display changes in events over time.

Physical resource was a pharmacist to prescribe or deprescribe based on evidence-based guidelines.

Advised the pharmacist of “actionable older adults receiving care” and recommended appropriate prescribing with the provider.

Involved reorganization and allocation of staff and dispatch of emergency vehicles.

**Overall Acceptability and Usability of Dashboards**

A summary of the users’ overall perceived acceptability and usability of the dashboards is presented in Table 4. Using the criteria described in the methods, perceived usability was mixed, with 4 studies reporting low [18,19,22,32], 5 medium [20,23,26,27], and 4 high usability [17,30,34,35]. Discrepancies between studies related to whether the dashboard was easy to learn, operate, and navigate, with some stakeholders feeling very confident using the dashboard [34] and others reporting difficulties with dashboard functionalities [17,23,27,33].

In terms of acceptability, most studies reported medium to high acceptance (10/11), with only 1 study revealing low acceptance [19]. While most respondents were willing to use the dashboard in their workplace (e.g., 94.4% agreement [34]), uptake was low (e.g., across 3 years, more than half of staff members logged in less than once [18]) and initial enthusiasm declined over time (e.g., [18]).

There was no distinct pattern of dashboard type (e.g., clinical and administrative), platform (e.g., ICT application and computer), or focus area (e.g., health status, administration, and medication) on reported dashboard usability or acceptability. Older adults tended to report usability as low (3/4 studies) [18,22,32], while other user groups (e.g., aged care staff) reported dashboard usability as medium to high (8/9) [17,20,23,26,27,31,33,34]. There were no noticeable differences between users on dashboard acceptability.
Table 4. Summary of overall usability and acceptability of dashboard.

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Dashboard type</th>
<th>User group (n)</th>
<th>Usability</th>
<th>Key findings</th>
<th>Acceptability</th>
<th>Key findings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>• Nurses (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bail et al [33] (2022)</td>
<td>Clinical</td>
<td>• Staff (65)</td>
<td>Medium</td>
<td>Interviews, focus groups, and survey: Users reported positively on the application across multiple devices, ease of access, scheduling and documentation of information at point-of-care (formatting and structure of alerts), and instantaneity of changes to care plan (rather than waiting hours to weeks). Some users felt that the app interfered with the rhythm of care (e.g., repetitive information), lacked training and login for agency staff, resulting in workarounds and missing data, and offering different styles of alerts and flagging (e.g., different adverse events and health conditions).</td>
<td>High</td>
<td>Interviews, focus groups and survey: Users reported reduced time spent on information retrieval and documentation; reduced errors by omission and missed documentation; improved staff and resident satisfaction; built consistency working with clinical treatment protocols; assisted management decisions and allocation of resources.</td>
</tr>
<tr>
<td>Bell et al [32] (2020)</td>
<td>Clinical</td>
<td>• Older adults in respite/long-term/other care (112)</td>
<td>Low</td>
<td>Survey: Little preference for using dashboard to receive prescribing notifications over traditional methods; user satisfaction, tool integration, and interface intuitiveness.</td>
<td>Medium</td>
<td>Survey: Percentage of time of prescribing recommendations accepted by skilled nursing facilities was adequate (66% uptake).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Physician (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Nurse (1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cui et al [34] (2018)</td>
<td>Clinical prototype</td>
<td>• Nurses (18)</td>
<td>High</td>
<td>Survey: TAMM found a large proportion of participants who found the dashboard easy to learn, use, and navigate (89%), and were satisfied with the component (100%).</td>
<td>High</td>
<td>Survey: TAMM results highlighting considerable perceived usefulness of the dashboard in improving assessment quality, collecting data, and standardizing information (100% of users).</td>
</tr>
<tr>
<td>Dowding et al [30] (2018)</td>
<td>Clinical prototype</td>
<td>• Nurses (292)</td>
<td>Medium</td>
<td>Survey: Large percentage of users who were able to use the dashboard immediately (91%) and use icons to switch between data types (96%). Heuristic evaluation and task analysis: Time taken to complete tasks differed (e.g., 5.7 minutes for nurses vs 1.4 minutes for expert users).</td>
<td>High</td>
<td>Survey: High SUS (73.2) and QUIST (6.1) scores for overall user reactions.</td>
</tr>
<tr>
<td>Author (year)</td>
<td>Dashboard type</td>
<td>User group (n)</td>
<td>Usability</td>
<td>Key findings</td>
<td>Acceptability</td>
<td>Key findings</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------</td>
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</tr>
<tr>
<td>Dowding et al [26] (2019)</td>
<td>Clinical prototype</td>
<td>Nurses (32)</td>
<td>Medium</td>
<td>Survey(^c): &gt;50% of participants had difficulty navigating dashboard and interpreting data in the dashboard due to interoperability.</td>
<td>High</td>
<td>Survey: High SUS (73.2) scores. Interviews: users valued the ability to see trends for vital signs over time.</td>
</tr>
<tr>
<td>Kramer et al [20] (2016)</td>
<td>Clinical simulation</td>
<td>Physicians (19)</td>
<td>Medium</td>
<td>Survey: High SUS (86.5) scores, however, reported improvements in accuracy (ie, number of medication reconciliation discrepancies using electronic dashboard vs paper) and amount of time to complete cases (ie, efficiency; reported similar completion time for paper-based process vs electronic dashboard) was mixed.</td>
<td>High</td>
<td>Survey(^c): Majority preferred the electronic module compared to paper-based processes (89.5% of users).</td>
</tr>
<tr>
<td>Lanzarone et al [27] (2017)</td>
<td>Administrative</td>
<td>Staff/other (-)</td>
<td>Medium</td>
<td>Survey(^c): Low completion times for task completion, increased distance traveled; however, there was minimal change in nurse allocated to visits (ie, good satisfaction among older adults receiving care) and low numbers of overloaded nurses.</td>
<td>Medium</td>
<td>Survey(^c): Mixed reports on the satisfaction of older adults receiving care, applicability of tool integration, and visualization of the information, with multiple recommendations.</td>
</tr>
<tr>
<td>Lee and Huebner [17] (2017)</td>
<td>Clinical prototype</td>
<td>Nurse (14)</td>
<td>High</td>
<td>Interviews: Users provided positive responses regarding the module’s ability to locate laboratory findings quickly, review information easily, and access decision support.</td>
<td>High</td>
<td>Survey(^c): High user ratings of clinical dashboard usefulness and necessity data (100%) particularly for supporting high-quality home health care.</td>
</tr>
<tr>
<td>Mei et al [23] (2013)</td>
<td>Clinical</td>
<td>Nurse (4)</td>
<td>High</td>
<td>Survey: High TAM(^g) scores (reported on system usability (eg, time taken to complete, the proportion of participants reporting ease of use) (100%).)</td>
<td>High</td>
<td>Survey(^c): High user agreement for improving job performance and accomplishing more work following system implementation.</td>
</tr>
<tr>
<td>Papaioannou et al [35] (2010)</td>
<td>Clinical, MEDeINR</td>
<td>Older adults (128), Physician (4), Nursing staff (8)</td>
<td>High</td>
<td>Survey(^c): 100% of users found the platform was easy/very easy to use with improvements in therapeutic range and time in sub/supratherapeutic ranges.</td>
<td>Medium to high</td>
<td>Survey(^c): 75% of users agreed platform decreased workload and 92% felt communication was better. Interviews: feedback found decreased anxiety around prescribing and emphasized improvements for training.</td>
</tr>
<tr>
<td>Shiells et al [19] (2020)</td>
<td>EHR(^h)</td>
<td>Staff (21)</td>
<td>Low</td>
<td></td>
<td>Low</td>
<td></td>
</tr>
<tr>
<td>Author (year)</td>
<td>Dashboard type</td>
<td>User group (n)</td>
<td>Usability</td>
<td>Key findings</td>
<td>Acceptability</td>
<td>Key findings</td>
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<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Wild et al [18] (2021)</td>
<td>Clinical, ambient</td>
<td>• Older adults in-home care (95)</td>
<td>Low</td>
<td>Interviews: Users reported a low preference for the device (preferring traditional methods of a desktop computer and paper) and its functionality, perceiving it as more work.</td>
<td>Medium</td>
<td>Interviews: Users reported a low preference for the device (preferring traditional methods of a desktop computer and paper) and its functionality, perceiving it as more work.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Staff (25)</td>
<td></td>
<td>Survey: Low proportion of users who logged into the dashboard (44%). Interviews: users reported technical difficulties and continued unfamiliarity with the system.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

aUsability refers to the extent to which the dashboard could be used by the specified users to achieve their goals effectively and efficiently.

bAcceptability refers to the satisfaction with the dashboard and future adoption by specified users.

cSurvey developed in-house by researchers.

dTAMM: Technology Acceptance Model for Mobile.

eSUS: System Usability Scale.

fQUIS: Questionnaire for User Interaction Satisfaction.

gTAM: Technology Acceptance Model.

hEHR: electronic health record.

**Dashboard Features**

An overview of the key dashboard features and their perceived acceptability is provided in Figure 2. The median number of features used in the dashboards was 6 and ranged from 4 [32] to 11 [27]. Displaying an alert (10/13) [17-20,22,23,26,27,30,32-35] was the most common, followed by customizable displays (8/12) [17-20,26,27,30,33] and the presence of color coding (7/12) [17,18,20,22,26,27,30,33]. One-third of the dashboards used symbols and icons (4/12) [17,18,26,27,30]. Visual graphs such as bar charts (2/12) [17,26,30,31] and line graphs (3/12) [17,18,26,30,31] were less frequently used in the dashboards. Functional aspects, including radio buttons (4/12) [20,23,26,27,30] and checkboxes (2/12) [23,34], were not used frequently.

The ability to update, alert, and generate reports for primary stakeholders was the most frequently used feature and was reported to be highly acceptable across all dashboard types. In general, features with high acceptability were bar charts, tables, icons, symbols, images, and color coding to organize and display information, as well as the use of radio buttons, the ability to expand and collapse information, and multiple displays to facilitate easy customization of the dashboard for different users. A small number of studies also described positional coding, checkboxes, and a completeness bar, which had high acceptability. One study of 195 nurses used a dashboard with spider and radar graphs, and these were reported as too complex [31].

There was only 1 study in-home care exploring older adults’ acceptability for line graphs, icons, and displays, all of which were rated as medium. Nurses tended to report communication features (eg, ability to converse with other users in the system) as low to medium [27,32], whereas older adults report it as high [22]. Compared to other user groups, older adults’ acceptability of alert features was variable, ranging from low to high acceptability.
Problems Identified With Dashboard Acceptability and Usability

Thirteen studies described problems hindering user acceptability and usability of dashboards. The main issues that decreased the overall acceptability and usability of the clinical dashboards included hardware problems, display options, and training. For older adults in home, respite, and long-term care, accessibility of a smart tablet was hindered by locking the tablet, having the incorrect pin code, and forgetting to charge the device [22]. Older adults within each care setting also appreciated a larger text display size and found the 3-step question design difficult when inputting information for a dashboard (eg, yes/no and subsequent questions as they have to recall the previous answer) [22]. For registered nurses, the existing workload prevented daily log-ins despite instructions [18,22]. Similarly, reliance on agency or outsourced workers meant that many staff did not have log-ins and prevented the use of the dashboard [33].

Training on how to use and navigate the dashboard was provided for most dashboard users; however, participant feedback on training ranged from low [32,33] to high satisfaction across studies [19,23,27,34,35]. In some papers, 3 training classroom sessions were sufficient [23], and in others, “on-the-job” training was preferred as an alternative to classroom-based learning [19]. In 1 study, more training was requested by new staff with suggestions for a designated nursing staff member to lead the training session, which could be a recorded session to enable easy dissemination [35].

Suggested areas for improvement across papers mostly related to reducing user workloads, ensuring the security and privacy of resident data, and strengthening decision support and communication features. Ensuring data remain private, particularly data on medication and prescribing patterns, was an emerging area for improvement, with a focus on having data available only to the relevant user [20,32]. Furthermore, inputting reasons for medication use would support nurses’ and clinician’s decision-making on medication administration, identification of discrepancies, and reconciling errors.

Although dashboards could be used to support interactions between different users (eg, staff, providers, and older adults), in 1 study, it was shown that users valued traditional methods of communication, particularly in relation to medication practices (eg, receiving pharmacist notifications separately).
rather than logging into the dashboard [32]. This was because users reported spending more time searching for appropriate medication-related information on the dashboard compared to routine practice (ie, predashboard) [20,32] and thus preferred alternative mediums (eg, sourced from electronic notes [32], phone calls [20], and face-to-face conversations [32]) to clarify discrepancies. Suggestions for dashboard functionalities to improve communication and reduce workload included (1) easy-to-navigate workflows [22,27,30]; (2) visual features that allow for better interpretability and usefulness (ie, simple graphs, customizable alerts, and appropriately positioned icons) [19,20,22,31,33]; and (3) timely responses between users to facilitate efficiency and confidence in medication reconciliation and management [20,23,32,35].

Discussion

Principal Findings

The aim of this review was to assess current evidence about the acceptability and usability of clinical dashboard features and functionalities in aged care environments. In general, users had high acceptability but mixed opinions on usability, with dashboards focused on administration activities having high acceptability. Dashboards that featured an update, alerts, and reports and those with simple visual elements (eg, bar charts, tables, and symbols) were considered highly acceptable, while those with complex features (eg, spider and radar graphs) had low acceptability.

Clinical dashboards are relatively new in aged care settings, despite these apps being used widely within population health and health services [49]. In our review, dashboards were developed to support a wide range of clinical and administrative purposes and had no distinct pattern of usability and acceptability on dashboard type or platform. Rather, our results suggest that the capabilities of the dashboards and how information is displayed to end users are more likely to influence the acceptability and usability of dashboards.

Previous studies reporting on the usefulness of other dashboard visualization features in health care settings may inform future dashboard design in aged care. For instance, clinicians prefer data tables as they perceive numbers as less “biased” than data that are presented in graphics [50-53]. Although not explored in the studies included in this review, visual aids such as league charts, caterpillar plots, or funnel plots can offer substantial benefits particularly if the purpose of the dashboard includes institutional performance comparisons (eg, comparing several aged care facilities in certain adverse health events). League charts are often desired because of their familiarity and simplicity [50,51]. Caterpillar plots and funnel plots, types of statistical process control techniques, are widely used visual aids for comparing the performance of institutions in certain performance indicator against a benchmark value [54]. Research shows that health care providers prefer caterpillar and funnel plots once they are taught how to read them [52]. A dashboard that includes specific values, as well as organizational comparisons in certain performance indicators may improve service processes and improve delivery of aged care quality [53]. Thus, when designing dashboards, data visualization approaches need to consider the target audience as well as dashboard purpose.

The perceived usefulness and acceptability of dashboards and their features may differ between end users. For instance, in this review, there were differences between older adults and other end users on the perceived usefulness of dashboards, with older adults likely to report usability as low, while other users reported it as medium-high. Such variability in the perceived usefulness of dashboards across end users can be minimized through customizable design [55], that is, engaging and considering the need of end users (eg, clients, staff members, and family) in the dashboard development process. A user-centered design approach would enable designers to gain an in-depth understanding of end user experiences, expectations, and needs for clinical dashboards, which are critical to addressing usability and acceptability issues and enhancing the likelihood of having an impactful and sustainable dashboard [56,57].

Implications and Recommendations for Future Dashboard Development

The findings of this study have important implications to guide future dashboard development. Dashboards often focused on 1 aspect of care (eg, clinical or administrative). While clinical outcomes are an important aspect of aged care quality, there is increasing understanding that a holistic resident or client trajectory should be key to understanding quality [58]. Future dashboards thus need to consider and construct an inclusive picture of resident or client needs to support the care continuum from entry in the system.

Our results found that dashboards typically used in-house collected data, with some using real-time reporting of information [18,27,30,35]. As reporting of quality indicators becomes mandatory in aged care sectors in many countries, the use of a dashboard makes it potentially possible to streamline and automate this process. This may relieve aged care staff of the significant time burden in collating and reporting these data [59]. It could also mean that reported data are more accurate as it removes some opportunities for human error and reports in real time.

Given that dashboards present data visually and aim to support users’ decision-making, the use of in-built decision support within a dashboard provides another opportunity for improved quality care. Recommendations in response to information presented in the dashboard could prompt end users to take appropriate actions to improve clinical care [17,26,30,32,35,60]. This review suggests that certain dashboard features are associated with increased usability and acceptability. For example, reduce user workload through customizability and interoperability of the dashboard, provide visual features to support timely interpretation and response, and include links to complementary information to strengthen confidence in clinical decision-making. Extending such decision support to enhance quality care could include alerts for allergies or special care needs, links to published guidelines to make users aware of appropriate care pathways, and medication errors such as duplications and interactions. Implementing evidence-based decision support to inform better care could be seen as highly...
beneficial within the aged care sector where health literacy levels vary greatly [61,62].

Limitations
There are several limitations to our review. The exclusion of gray literature, small number of studies fulfilling the inclusion criteria, and poor quality of the included studies are current drawbacks. Furthermore, most of the studies included in the current review did not explore the potential effect of their dashboards on outcomes and care processes (eg, documentation of care processes and better health outcomes). Due to the nature of reporting in each of the study’s findings and the variation in type and size of end user groups, it was not feasible to determine the differences in usability and acceptability between individual groups; thus, our findings are a summary of all respondents. Future research should focus on how the introduction of different types of clinical dashboards could support adherence to quality guidelines and understand dashboard design and usability in terms of mixed versus specific user groups. Identification of areas where dashboards should be most appropriately introduced to target specific initiatives should also be considered (eg, older adults with dementia and home care) to help improve the quality of care. Further work is needed to explore how users understand and interpret dashboard features, their preferences for information presentation, and how the information is used to support care or service planning, decision support, and user behavior.

Conclusions
Users found dashboards in aged care generally highly acceptable, particularly those with simple visual elements and features such as an update, alerts, and reporting functionalities. This review highlights the variability in the usability of dashboards and identified certain design features of dashboards, which are associated with increased usability and acceptability. Four possible advantageous features and functionalities for future dashboard developments within aged care are emphasized. Specifically, customizability and interoperability to account for different end user preferences; incorporating numerical (tables) and graphical (league and caterpillar charts) presentations of data to facilitate accurate individual assessment and comparison (benchmarking) respectively; integrating changes to client care preferences with real-time clinical outcomes for a holistic representation of the care journey; and building in recommendations and alerts for best practice clinical decision-making to reduce error and support appropriate care pathways. However, further research on the development, testing, and implementation of visualization dashboard solutions to support outcome improvement for older adults is required.

Authors' Contributions
All authors contributed to the conception of the review. JS led the design of the review, with input from all authors. JS, FS, and LD reviewed the retrieved references, with AN acting as fourth reviewer. Papers were retracted by JS, with assistance from LD and AN. JS reviewed the full-text papers, with LD and AN acting as second reviewers. JS, KS, and MR conducted the risk of bias assessment. Data extraction and quality assessment were undertaken by JS and LD. JS led the writing of the manuscript, with all authors contributing or providing feedback and approving the final version of the manuscript.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Supplementary material.
[DOCX File, 24 KB - aging_v6i1e42274_appl.docx]

References
3. Stadler JG, Donlon K, Siewert JD, Franken T, Lewis NE. Improving the efficiency and ease of healthcare analysis through and interpretation of dashboard features, their preferences for information presentation, and how the information is used to support care or service planning, decision support, and user behavior.

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Abbreviations

ICT: information and communication technology
MMAT: Mixed Methods Appraisal Tool
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
TAM: Technology Acceptance Model

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Pioneering the Metaverse: The Role of the Metaverse in an Aging Population

Sara Shu1,2, DO; Benjamin K P Woo2,3, MD

1Department of Family Medicine, Mayo Clinic, Rochester, CA, United States
2University of California, Los Angeles, Sylmar, CA, United States
3Chinese American Health Promotion Laboratory, Los Angeles, CA, United States

Corresponding Author:
Sara Shu, DO
Department of Family Medicine
Mayo Clinic
200 First Street SW
Rochester, CA, 59905
United States
Phone: 1 858 761 7863
Email: shus@g.ucla.edu

Abstract

Amid a worldwide pandemic in the setting of an era of rapidly developing technologies, we turn now to the novel and exciting endeavor of pioneering the metaverse. Described as the conglomeration of augmented reality, virtual reality, and artificial intelligence, the metaverse has widespread applications in multiple settings, including revolutionizing health care. It also holds the potential to transform geriatric medicine, introducing new dimensions through which we can prevent social isolation, encourage health and well-being, and offer a new dimension through which we manage chronic disease. Although it is still a futuristic and novel technology, the metaverse’s realization may indeed be closer than we think.

(Keywords: metaverse; older adult; aging in place; dementia; gerontology; geriatric; digital health; digital technology; computer generated; artificial intelligence; virtual reality; mixed reality; augmented reality; aging; mental health)

Since the introduction of the World Wide Web, possibilities and imaginations have proliferated and expanded, and they have revolutionized the dissemination and sharing of information, communication, and connectedness through social media, videoconferencing, and gaming platforms. The metaverse, a term symbolizing the intersection of physical, augmented, and virtual reality in a shared web-based arena, was originally coined from the 1992 sci-fi novel Snow Crash [1], and it has now eerily become a tangible reality of the near future.

Technologies over the years have included many advances in virtual reality, augmented reality, artificial intelligence, and now the metaverse. The ability for people’s avatars to interact in real time with each other, much like what we see in the gaming industry with games like Roblox (Roblox Corporation) and Animal Crossing (Nintendo Co, Ltd), will soon become prevalent on social media and videoconferencing platforms—a virtual teleportation into digital space that will enable the transcendence of space and time. The surge in technology, further bolstered by the COVID-19 pandemic, has transformed our videoconferencing platforms to enable work-from-home meetings, medical appointments via telehealth, and education across all levels. In the scientific community, conferences turned to virtual reality, using surprisingly interactive and advanced technologies, thereby enabling personal interaction via avatars among professionals across the globe. Virtual workspaces are currently being prototyped by companies like Microsoft. Facebook’s recent announcement, in which they pledged their pursuit of such future capabilities and stated that they were officially changing their name to Meta, set the stage for the next generation of technology [2].

Already, many have surmised the role of the metaverse in transforming health care in cardiovascular medicine, spine surgery, gynecology, behavioral and mental health, and even dentistry [3-8]. Such a novel concept opens possibilities for far-reaching applications, including using the metaverse to transform care for the aging population. With so many now
interested in pioneering the metaverse, we can also take part in exploring what the metaverse can implicate in the lives of the older adult population. Digital presence in a time when physical presence is becoming less common and more difficult, such as during the current COVID-19 pandemic, makes us wonder whether the metaverse can truly be used toward promoting a society of intergenerational connectedness.

The COVID-19 pandemic has certainly highlighted the impact of social isolation on psychosocial health not only in the older adult population but also across all ages [9]. Fostering socialization through the use of technologies during this time has been an all too welcome solution. Older adults already experience the highest rates of social isolation and loneliness [10]. Combating this by facilitating socialization among loved ones already helps to decrease one of the leading causes of mortality in this population. Videoconferencing technologies enable social interaction with loved ones across the globe. The ability to interact with avatars or digital twins of loved ones in a virtual space will ultimately enhance the notion of presence when otherwise physically impossible [11].

These so-called digital twins provide yet another way through which medical visits may be augmented in the metaverse. Essentially virtual representations using real-time data that enable the running of endless simulations and extend to the human being, digital twins have the potential to guide disease management and become a tool for personalized and directed health care. Already, companies like Philips are developing technologies for creating digital twins of human hearts to help guide personalized medical decision-making and treatment [12]. Telehealth provides people living in remote areas or people who are otherwise unable to physically present to a clinic with the ability to carry out health care visits in virtual reality—another dimension that can enhance virtual diagnoses and care.

The use of such technologies can however prove challenging in older persons with reduced visual acuity, reduced manual dexterity, and cognitive impairment. Technological advancements have overcome some of these barriers, serving to improve functioning, tracking, and mobility, and have the potential to not only alleviate caregiver burden but also enable individuals to successfully age in place [13]. Alternately, there exist multiple forms of computerized cognitive training programs, or serious games (named as such due to their primary purpose being other than pure entertainment), that have been shown to help improve verbal, nonverbal, and working memory and therefore potentially have a role in slowing or preventing cognitive decline [14,15]. Incorporating cognitive training strategies is another application of the metaverse for this population.

The metaverse also holds the potential to address aspects of well-being, such as exercise and fitness. Much like the Wii Fit (Nintendo Co, Ltd) did for encouraging engaging in at-home workouts, nowadays apps like Supernatural (Within Unlimited, Inc) and FitXR (FitXR Limited) provide a means to exercise via virtual reality. Studies on virtual exercise via virtual reality applications and games have shown that these are viable modes of exercise that are able to elicit exercise intensities matching those in recommended guidelines and are being further studied to help inform developers about integrating exercise in the metaverse [16,17]. Integrating metaverse fitness into at-home exercises targeted toward older adults can help them to enhance their fitness in the comfort of their own homes. With the help of virtual reality, at-home exercise also can prove to be a means of helping someone to exercise when otherwise unable.

The first dementia villages were built in the Netherlands and Germany and introduced a novel concept of communal care, focusing on the psychological and emotional needs of those with dementia [18]. In the United States, the first dementia village—Glenner Town Square, San Diego, California—was built in 2018, using the setting of a 1950s town, and such villages are now being franchised and recreated around the country [19]. These villages were built on the concept of reminiscence therapy and its potential benefit on cognition and mood in individuals with dementia [20]. Now, we can extend the creation of dementia villages into the metaverse by creating a digital “virtual playground,” so to speak. Individuals would be able to transcend time by going back to any time and any town of their choosing and enjoy the things with which they are familiar. Such reminiscence therapy can help individuals with dementia age with dignity by allowing them to find comfort in the memories of their past.

Through the metaverse, loved ones separated by physical distance may be able to interact within a virtual space in real time. Perhaps soon we will be able to create virtual spaces filled with specific memories of our own childhoods and store these memories to be able to share them with our future generations, so that they may be able to catch a glimpse of the world in which we once lived. As Amazon recently announced its current endeavor to develop artificial intelligence technology to enable Amazon Alexa to mimic voices of deceased loved ones, the capability to preserve or leave behind a piece of what was lost hints at the endless innovations to come [21]. The thought of this all too attainable future sounds like an episode from Black Mirror. Indeed, we are finding ourselves in a “digital catch-22” in which the potential benefits of virtual reality, augmented reality, and artificial intelligence technologies are ultimately dependent on having the desire to use these technologies and the knowledge and access to do so [22].

In pioneering the metaverse, future studies should focus on amplifying the potential of this virtual world in directly improving the mental health, and even indirectly improving the physical health, of the aging population. With the current paucity of evidence and developed technologies, there exists an urgency to invest resources to develop and apply such technologies for the care and well-being of our aging population. A once far-fetched, science-fictional imagination is now within our grasp.

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**Conflicts of Interest**

None declared.

**References**

Viewpoint

Proactive and Ongoing Analysis and Management of Ethical Concerns in the Development, Evaluation, and Implementation of Smart Homes for Older Adults With Frailty

Rosalie H Wang1,2, BSc, BScOT, PhD; Thomas Tannou3,4, MD, PhD; Nathalie Bier3,5, BScOT, MSc, PhD; Mélanie Couture6, BA, MA, PhD; Régis Aubry4, MD, PhD

1Department of Occupational Science and Occupational Therapy, Temerty Faculty of Medicine, University of Toronto, Toronto, ON, Canada
2Rehabilitation Sciences Institute, Temerty Faculty of Medicine, University of Toronto, Toronto, ON, Canada
3Centre de recherche de l’Institut universitaire de gériatrie de Montréal, Centre intégré universitaire de santé et de services sociaux (CIUSSS) - Centre-Sud-de-l’île-de-Montréal, Montréal, QC, Canada
4Centre d’Investigation Clinique de l’Institut National de la Santé et de la Recherche Médicale (INSERM CIC) 1431, Centre Hospitalier Universitaire de Besançon, Besançon, France
5Programme d’ergothérapie, École de réadaptation, Faculté de médecine, Université de Montréal, Montréal, QC, Canada
6École de Travail social, Université de Sherbrooke, Sherbrooke, QC, Canada

Corresponding Author:
Rosalie H Wang, BSc, BScOT, PhD
Department of Occupational Science and Occupational Therapy
Temerty Faculty of Medicine
University of Toronto
160-500 University Ave
Toronto, ON, M5G 1V7
Canada
Phone: 1 416 946 8566
Email: rosalie.wang@utoronto.ca

Abstract

Successful adoption and sustained use of smart home technology can support the aging in place of older adults with frailty. However, the expansion of this technology has been limited, particularly by a lack of ethical considerations surrounding its application. This can ultimately prevent older adults and members of their support ecosystems from benefiting from the technology. This paper has 2 aims in the effort to facilitate adoption and sustained use: to assert that proactive and ongoing analysis and management of ethical concerns are crucial to the successful development, evaluation, and implementation of smart homes for older adults with frailty and to present recommendations to create a framework, resources, and tools to manage ethical concerns with the collaboration of older adults; members of their support ecosystems; and the research, technical development, clinical, and industry communities. To support our assertion, we reviewed intersecting concepts from bioethics, specifically principlism and ethics of care, and from technology ethics that are salient to smart homes in the management of frailty in older adults. We focused on 6 conceptual domains that can lead to ethical tensions and of which proper analysis is essential: privacy and security, individual and relational autonomy, informed consent and supported decision-making, social inclusion and isolation, stigma and discrimination, and equity of access. To facilitate the proactive and ongoing analysis and management of ethical concerns, we recommended collaboration to develop a framework with 4 proposed elements: a set of conceptual domains as discussed in this paper, along with a tool consisting of reflective questions to guide ethical deliberation throughout the project phases; resources comprising strategies and guidance for the planning and reporting of ethical analysis throughout the project phases; training resources to support leadership, literacy, and competency in project teams for the analysis and management of ethical concerns; and training resources for older adults with frailty, their support ecosystems, and the public to support their awareness and participation in teams and ethical analysis processes. Older adults with frailty require nuanced consideration when incorporating technology into their care because of their complex health and social status and vulnerability. Smart homes may have a greater likelihood of accommodating users and their contexts with committed and comprehensive analysis, anticipation, and management of ethical concerns that reflect the unique circumstances of these users. Smart home technology may then achieve its desired individual, societal, and economic outcomes and serve as a solution to support health; well-being; and responsible, high-quality care.
Canadians are estimated to experience frailty. Frailty is an umbrella term that encapsulates a constellation of conditions with varying severity and consequences for individual older adults. It presents with poor health and function and heightened vulnerability to incidental adverse health events and deteriorating quality of life [10]. The integrated model of frailty developed by Gobbens et al [11] highlights 3 major components of frailty—physical, psychological, and social—that dynamically interact to create this situation of vulnerability. For example, a diagnosis of frailty may be assigned if physical conditions (eg, malnutrition or mobility restrictions because of arthritis) that may affect or be affected by psychological capacity (eg, cognitive decline caused by Alzheimer disease or low mood because of depression) co-occur with an unsupportive social situation (eg, poor social relations or isolation). In such a scenario, an adverse event such as a fall is more likely to occur and may cause an older adult to reduce social activities and isolate at home. A vicious cycle may thereby be created and further increase the risk of falls and physical, psychological, and social vulnerability. Without intervention, interactions between these frailty components may lead to the following: (1) disability or difficulties performing self-care and household management activities, creating dependency; (2) falls and mobility reduction; (3) hospitalizations; (4) changes in living situations (eg, moving to a long-term care home); and (5) death. However, frailty, depending on the modifiability and interactions of the diseases and conditions, may be preventable and reversible with appropriate interventions [12].

Research suggests that frailty may be viewed as progressive alterations in an older adult’s intrinsic capacities (ie, motor skills, cognition, and sensory functions), suggesting reversibility through strengthening of these altered capacities with health and social interventions (eg, physical and cognitive rehabilitation and participation in valued social and community activities) [13]. As such, it is imperative to identify frailty (or the risk of frailty) and implement early intervention. However, with persistent impairments, support strategies may be based on compensation for the loss of capacity and function to reduce dependency [14]. Social support and technology may be crucial environmental elements in early detection and intervention [5,15]. Digital solutions such as smart home technology may play key roles in mitigating some of the causes and consequences of social isolation and frailty [16] while respecting older adults’ right to self-determination.

**Smart Homes**

Smart homes may be interventions to address pressing concerns about supporting the high quality of life of older adults, relieve stressors on informal supports, and mitigate the challenges of health and social system sustainability with population aging. Users of smart homes may include older adults and members of their support ecosystems (ie, family or friends in caregiving roles, physicians, therapists, social workers, nurses, and home support workers) [17]. (Additional users necessarily include the...
research, technical development, and industry communities as they are responsible for data maintenance and support for use.) The combination of smart home technology and human support constitutes a powerful environmental support strategy. Indeed, these homes may be viewed as an embodiment of the collective human intelligence. This collective intelligence may support shared goals and respect the older adult and members of their support ecosystem. This may be done by supporting decision-making processes and affording efficient, personalized, and adaptive management of frailty in older adults living at home.

Smart home technology may assist with daily activities in various ways. Broad functions may include home environment or appliance automation (eg, thermostat control and stove shutoff), health or activity tracking for self-management purposes, monitoring and alerting for safety or emergency situations, and supporting social connectedness [17,18]. Sensors embedded in a home may collect longitudinal data to monitor a resident’s health status, behaviors, and activities. Important frailty-related information regarding cognition, mobility, and daily activity performance status may be monitored and inferred through activity patterns and indicators [5,15]. Data integration and analysis using artificial intelligence (AI) approaches such as machine learning may allow for the creation of tools that predict or detect events. The detection of adverse events such as falls or concerning trends in health, such as a routine disruption that may suggest the occurrence of a delirium, may expedite access to intervention from caregivers and health care providers. Reminders or stepwise assistance to perform daily activities may be delivered based on the system’s input, observed, or learned knowledge of residents’ behaviors, activity patterns, and preferences. Residents may interact with a smart home through various interfaces involving voice, touch, motion, or gestures [19]. Although many specialized smart home products and services are in development for older adults with health needs [4], there is also a proliferation of technology for general consumers that offers desirable functions for older adults to enhance environmental comfort (eg, automated control of lights or thermostat), safety (eg, home security systems and automated door locks), and daily activity performance (eg, kitchen appliances).

Despite innumerable smart home projects at various phases of development and implementation worldwide, the vast majority are not realized into commercial products and services, and mainstream technology on the market has not been widely adopted by older adults [18,20]. Ethical challenges have been reported to influence the successful adoption and sustained use of smart homes [21]. There is also increased focus on systematically considering ethics as part of the Health Technology Assessment that supports policy recommendations for available technology [19,22,23]. Nevertheless, little attention has been paid to ethical evaluation during the design of intelligent assistive technology such as smart homes [24,25]. Few researchers have highlighted the imperative for comprehensive inclusion of ethical considerations across processes for development, evaluation, implementation, and the sustained use of smart home technology. As such, we assert that proactive and ongoing analysis and management of ethical concerns are crucial to the successful development, evaluation, and implementation of smart homes for older adults with frailty.

Concepts and Ethical Challenges

Overview

Ethical challenges and the need for deliberation arise when anthropological concepts such as values conflict with other values that are considered equally important. Applied ethics is the field that examines real-world applications of this deliberation and action. We bring together concepts from often-siloed fields of bioethics, such as principlism and ethics of care, and technology ethics to highlight ethical challenges to be deliberated with respect to smart home technology.

Principlism

Principlism by Beauchamp and Childress [26] refers to a dominant framework in bioethics that outlines 4 key principles—respect for autonomy, beneficence, nonmaleficence, and justice. Although the latest edition of Beauchamp and Childress [26] includes discussions of moral virtues and features of the professional-patient relationship, such as veracity, privacy, confidentiality, and fidelity, the 4 principles remain pillars of bioethics. Autonomy is the fundamental right to make decisions about oneself and to do what one chooses within one’s own life. A distinction can be made between being autonomous and independent. Being autonomous means being able to express and act in terms of one’s own free will, which may include choosing to receive assistance from others. Being independent means not requiring assistance from others. Beneficence relates to the responsibility to act in ways that benefit others overall, which may include preventing, mitigating, and removing harm to others and promoting benefits. Nonmaleficence refers to the responsibility to abstain from or avoid actions that cause or may cause harm to others. Justice is the principle that is concerned with fairness (treating everyone with the same concern and respect) and equity (seeing that benefits and harms are distributed across people as equals) [27].

Ethics of Care

Although ethics of care, or care ethics, may be positioned as an alternative to the rationalist principle-oriented perspective of principlism [28], it is valuable to consider both approaches as they are complementary when examining the management of frailty in older adults. Maio [28] concentrates on the core ideas of care ethics without invoking the historical gendered view of care and ethics. Fundamentally, the ethics of care deals with the asymmetric nature of care relationships and the potential dependency and vulnerability that can result. Furthermore, assuming that care relationships are, to varying degrees, asymmetrical does not deny the equality of people in care-associated relationships and the sovereignty of individuals to determine their life and care goals. On the contrary, it requires all participants to appraise this vulnerability to offer adequate support. In this way, according to Maio [28], ethics of care must be situation-oriented; responsive; and informed by knowledge from experiences, relationships, and the situation at hand.

In details, according to the revised version of the 4-phase model of care by Tronto [29], ethics of care leads to acceptance of
fundamental dependency on and need of mutual support (Conradi, 2001, as cited in Maio [28]). Attentiveness is the first step to be able to care about someone else. Keeping in mind the concern for the other leads to an inclination to respond to their needs. This response to another’s needs is grounded in a sense of responsibility and translates into direct action or chains of action depending on the competencies of caregivers and singularities of each situation and relationship. Individual competency and the ability to initiate the required chain of action to manage the situation are key. The ability to provide a solution or initiate a chain of solidarity to support an identified need is the basis of ethics of care.

Technology Ethics

There is currently no dominant or unified approach to technology ethics. Ethical issues, implications, and decision-making practices arising from the design, use, and spread of different technologies are much-discussed topics in different fields and referred to using various terms (eg, technoethics, ethics of technology, computer ethics, AI ethics, and machine ethics). Consistent across these fields is the need to examine ethical, social, and legal implications, and there is often an orientation toward supporting citizens’ rights [30]. Many concerns are based on the rapid evolution of digital technology and AI, which raise new questions, possibilities, and challenges that require careful deliberation. Technological developments may have a range of intended and unintended uses and outcomes or may amplify existing societal problems. Indeed, care ethics, with its emphasis on personal relationships, may rightly or wrongly subordinate care delivered through technical means in relation to human care [30]. These developments require us to continuously reflect on and modify our individual and collective values and practices.

Concepts in technology ethics are numerous and often include those of bioethics. Friedman and Kahn [31] in the field of human-computer interaction outline 12 human values they consider to be ethically important in computer ethics. The 12 values are human welfare, ownership and property, privacy, freedom from bias, universal usability, trust, autonomy, informed consent, accountability, identity, calmness, and environmental sustainability. In the Institute of Electrical and Electronics Engineers Global Initiative on Ethics of Autonomous and Intelligent Systems, 5 general ethical principles were identified as critical in the design, development, and implementation of technology: human rights, well-being, accountability, transparency, and awareness of misuse [32].

### Ethical Challenges Related to Smart Homes for Older Adults With Frailty

#### Overview

Bioethics and technology ethics concepts are salient but intersecting. Examining these concepts in relation to smart homes for use by older adults and in the management of frailty can lead to ethical challenges. We describe in depth 6 key conceptual domains that need to be analyzed for smart homes but that can lead to ethical tensions.

### Privacy and Security

Privacy and security concerns are multidimensional and often interrelated. There are 2 dimensions of privacy that warrant examination: privacy of personal information (ie, identity) and physical privacy (ie, related to one’s body and the activities and routines being carried out in different spaces) [24]. Security may refer to information security or the safeguarding of data from unauthorized access. In addition, security may pertain to the experience of safety or trust in someone or something in a situation.

Information privacy and security are linked as maintaining privacy necessitates the security of information. Ethical concerns relate to the vast amount of sensitive information (eg, personal, medical, physiological, behavioral, and locations) that may be collected from users, how and for what purposes the information may be used, and who has and should have access to the information (eg, family, friends, health care providers, insurers, and manufacturers). Furthermore, the loss of private and confidential information to crime or unauthorized or wrongful access and use may lead to safety concerns and loss of the feeling of security [19]. Of particular importance to older adults with cognitive impairments or who are dependent on others are the experiences of uncertainty regarding what information is being collected, who has access (both intentional and unintentional in the case of an information breach), whether access may be controlled by users or others, and how reliable and trustworthy are those who have access. In such cases, harm may be inflicted without the older adult’s knowledge or control.

Privacy concerns are commonly voiced by older adults when considering smart homes and their adoption [18,20,33]. Facilitating personal safety and feelings of security is important for living at home autonomously and may be a strong motivator for adoption. There may need to be a trade-off between gaining security (and, thereby, freedom) and the loss of privacy if activities or routines in the home are monitored [19]. When older adults and those in their support ecosystems are trying to enhance safety and security with remote monitoring (eg, installation of cameras or other sensors in the bathroom to alert for assistance after a fall), a balance needs to be created when setting up systems to see that older adults’ privacy rights and personal wishes are respected. Older adults with cognitive impairments may need more monitoring as they may be at greater risk of harm [19] but less able to express their wishes.

Issues of privacy loss may be mediated by perceptions of the smart home technology’s usefulness. If the functions or services provided by the technology are perceived to be beneficial, older adults may elect to disregard some privacy concerns [24,33]. Some studies have reported that people with better health prioritize privacy protection more than those with poorer health and that those with poorer health prioritize the potential benefits of technology use [18]. However, there may be a tendency for older adults to favor conservative options when presented with novel, uncertain, or even risky situations [34]. That is, in making decisions, they may elect to implement strategies aimed at avoiding losses rather than optimizing gains. This prospect may need to be accounted for in decision-making regarding the adoption and use of smart home technology. There may also be

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scenarios in which older adults with cognitive impairment do not perceive a risk and feel safe despite the heightened risk related to frailty. In such cases, they may reject technological assistance based on its perceived nonusefulness. These trade-offs among the need to maintain privacy standards, minimize losses, and accept benefits necessitate heightened awareness to ensure that older adults who may be vulnerable are not exploited and able to make the best decision for their situation.

**Individual and Relational Autonomy**

An important dimension of autonomy involves older adults’ relationships with others in their support ecosystems, as underscored in care ethics. Individual autonomy is the right of individual older adults to make choices about their lives and act freely without external influences [26]. However, in care contexts, relational aspects are critical, whether they are with other people or environmental elements such as smart homes [35,36]. In relational autonomy, dynamic interactions between individuals and others around them cocreate an individual’s identity, interests, and needs. The reality when considering respect for autonomy is that decisions of older adults regarding how they are supported (eg, by other people, technology, or a combination of these), what support they accept and when, what benefits are desirable, or what risks or harms are acceptable are affected by and will affect those around them. For instance, in cohabitation situations where remote home monitoring is considered, decisions affect others directly, so collective privacy needs to be discussed [30].

Some research has identified that caregivers perceive the benefits of technology use more than older adults who feel they may do without technological support [18]. Family members have reported feeling trust in the technology and that it would help their older relatives carry out more activities on their own, whereas older adults felt that smart homes may help in emergency situations but reported feeling more secure with another person present [17]. Overemphasis on either individual or relational perspectives has been critiqued as one may risk neglecting collective decision-making to benefit individuals and the other may neglect individual older adults’ needs over those of others. The relational influences of ethical import on the adoption and use of smart homes for older adults with frailty and enhanced vulnerability may include positive and negative social pressure, persuasion, or even coercion from family, friends, or other social forces [18].

Beyond autonomy in care relationships with other people, ethical concerns have been raised regarding responsibilities with technology in the management of health and social needs. Concerns have been identified over the loss of individual autonomy with technology use in circumstances where it is perceived to control what older adults do or provide too much assistance [19]. Fears may be experienced by older adults and those in their support ecosystems that they may become overreliant on technology or automation [19].

Respecting the autonomy of older adults and their support ecosystems individually and within relationships may necessitate the adoption of the tenets of care ethics and the application of a support ecosystem–centered approach. Information about and experience with using smart home systems needs to be personalized to support their collective goals and informed decision-making about use. Notably, older adults with cognitive impairments may require additional considerations for making their needs known and support in shared decision-making [37]. The original theory of discourse ethics by Habermas [38], which emphasized the imperative for intersubjectivity in arriving at moral standards [39], may be pertinent to decision-making in relational autonomy. The theory with key concepts adapted by Frantik [40] to be inclusive of people with dementia may be particularly useful as it affirms their rights and empowers them through practical strategies to participate equally in negotiations that result in decisions affecting their lives.

**Informed Consent and Supported Decision-making**

Informed consent may only occur when people have knowledge and understanding of technology, their intended purposes and uses, and the potential benefits and harms the technology may create for them and their situations. A lack of awareness, familiarity, knowledge, and skills associated with smart home technology undermines consent capacity. This may have implications for adoption and use, the selection of options or features to maximize benefits and minimize risks during use, and consent to terms of service or data use [20,25,33]. These gaps may lead users to distrust technology or reject its use as they experience a loss of autonomy. Users may not even be aware of or comprehend the fact that these are ethical concerns [24].

Requirements for informed consent become more complex and unfeasible with the addition of AI to smart home technology because of limitations in the transparency and traceability of algorithmic decisions [25,30,41]. Transparency issues relate to how well users may understand how decisions are being made. With AI, large data sets are processed continuously and used to autonomously learn about users and make decisions to eventually carry out a desired action. Decision-making opportunities are not presented to users, so they do not have explicit choices, and it is unrealistic for users to make all these decisions. Algorithms tend to be opaque such that the decisions of the system cannot be explained [30]. Furthermore, algorithms evolve over time, whereby the functions and abilities of algorithms may no longer be consistent with those that users granted their consent for [25]. Although users are asked to consent to sharing a lot of their data, it may be challenging for users to assess benefits and harms. Indeed, developers who use the data and algorithms cannot adequately assess the benefits and harms as the exact ways in which decisions or actions are determined from the algorithms may be unknowable. Traceability refers to whether the cause of harm may be identifiable in situations where multiple actors are involved in the creation or implementation of an algorithm and who may be accountable and liable for harms [41].

Informed consent by older adults also depends on the availability of high-quality information. The proliferation of misinformation creates challenges in disentangling information and finding information from trustworthy and reliable sources. Unscrupulous or unknowledgeable individuals may also sell products or services targeted at older adults that overemphasize benefits and minimize potential harms. Considering older adults’
tendency to select options that minimize losses in novel circumstances, how or by whom information is presented may be more important than what is presented. Older adults, especially those with cognitive impairments or who are socially isolated, may be particularly vulnerable to mistreatment related to the trustworthiness of information.

Without accessible information or appropriate learning opportunities that are oriented to enhance understanding by older adults who may be unfamiliar with technology or have cognitive limitations, informed consent and decision-making may not be possible. The information offered to older adults may be overly simplistic (ie, merely asking for agreement to use a service) or complicated (ie, detailing specifics of terms of service) [24]. Even in the absence of disease, cognitive aging is associated with a decline in information-processing speed. As such, the ability to make decisions is preserved only when enough time and explanations are provided in an environment where distractions are minimized [34]. For some older adults with cognitive impairments, the availability of ongoing decision-making support may be essential across the spectrum of cognitive abilities. For example, trained and trusted family members, health or social care professionals, or substitute decision makers may be essential to explain information in understandable ways or grade decision-making to match the abilities of the older adult. Determining advanced directives for older adults with cognitive impairments may be a possible solution, although assent will continue to be required by assessing older adults’ verbal or nonverbal signs of agreement or disagreement in specific situations [25].

Social Inclusion and Isolation

Commonly discussed functions of smart homes are to enhance social connectedness, support, and inclusion; reduce isolation through remote communication with caregivers or health care providers; and offer ready access to assistance in emergency situations. Given the anticipated shortage of healthcare providers and working-age caregivers and changes in family living arrangements, with younger generations living further away from senior family members, care from a distance through technology is increasingly the reality [42,43]. For some older adults have voiced concerns over the potential loss of social contact and human touch when care technologies such as smart homes are suggested [18-20,33]. With the capabilities of AI, there may be the added threat of replacing care providers and further compromising relationships [44]. Considering care ethics, relationships and experiences of empathy and responsiveness to needs are critical. As such, technology serves as an augmentative tool and one of several elements of personalized care. Overreliance on technology-based care, whereby technology is applied as a substitute for in-person interactions, may have detrimental effects in situations involving older adults with frailty. Nevertheless, a possibility may be that some older adults wish to include technology in their health management to limit social contact, preserve private time, or protect privacy [19]. Considering the social needs of older adults and members of their support ecosystems relates back to respecting autonomy in the management of frailty. Beneficence and maleficence also need examination to balance the overall benefits and harms of the use of smart homes as components of health and social care for those involved.

Stigma and Discrimination

Stigma and discrimination are concerns that may vary across sociocultural contexts and result in considerable harm. These concerns are pertinent to older adults’ adoption and use of smart home technology and are important in the development and implementation of potentially beneficial technology. Stigma may be defined as “a set of negative and often unfair beliefs that a society or group of people have about something” [45]. Stigma is associated with being an older adult (ie, being elderly and senile) or having a disability and the perception of being a burden. Older adults have expressed concerns over the stigma associated with the technology used to support health and social care [18,33]. The use of such technology may be perceived to reflect diminished health and increased frailty and disability—characteristics with which older adults may not personally identify. The obtrusiveness of technology (eg, whether installed components or functions are clearly visible or audible to others and call attention to personal problems) has an influence on its adoption by older adults [20]. The perception and experience of stigma with the use of smart homes may result in older adults’ rejection of potentially useful tools to support their goals.

Discrimination is “the practice of unfairly treating a person or a group differently from other people or groups of people” [46] and is often the result of unfair and negative beliefs. Ageism (negative attitudes toward aging or older people), ableism (negative attitudes toward people with disabilities and their potential achievements), and mentalism (negative attitudes toward people with mental health or cognitive disorders) are all causes of discrimination. Discrimination may negatively influence what and how smart home technologies are developed. The choice of technology functions to create or the goals achievable by the technology may be informed by unfair beliefs about older people or people with disabilities. The lack of available data sets representing diverse age groups and abilities to inform AI development for these applications may be reflective of negative attitudes and contribute to the considerable problem of AI bias. What is considered normal or healthy may be determined by a small subset of people and their biases (eg, industry) [41]. Consequently, the developed functions or applications may not work for older adults with disabilities, or the decisions made by AI algorithms may not reflect the decisions of these users [41]. The inclusion of AI may not make decision-making more objective, and thus, predictions or recommendations should be used as guidance rather than as definitive decisions. Furthermore, even if technology is available, it may not be offered to older adults. This may be because caregivers, health care providers, or others may believe that older adults are not interested in it, are incapable of learning to use it, or will not benefit as much from it as younger people.

Equity of Access

Equity of access to beneficial support that may enable health and well-being is a concern of justice. Being equitable may involve “treating people or distributing resources differently, when people are in different situations and unequal treatment
or distribution creates an equal outcome” [27]. A concern is whether the availability of smart home technology with its associated costs will only benefit people who can afford to pay for it [19,25,33]. Inequitable access may result in older adults who are unable to pay (or without family support to pay) being excluded from the benefits of smart homes, experiencing poorer health and well-being, and being further socially excluded. At a societal level, this may deepen the existing digital divide, whereby only privileged groups benefit from the use of digital tools and broad adoption is restricted. Nonetheless, the cost of smart home technology is anticipated to be driven down as it becomes more available and prevalent (though initially for those who can pay) and technology production costs decrease. In recent years, technology to support health and social care for the growing older adult population has become an important development topic for industry.

Government policy makers have also considered the topic critical in policy actions to ensure the health and well-being of citizens and the sustainability of funding to support care systems. In managing resources and spending priorities, there is a need for consideration and evaluation of the cost-effectiveness of smart home implementation for older adults with frailty and the intended goals [19]. Policies that allow for faster uptake of smart home technology by everyone may require more insurance-based reimbursements in health care plans [25]. Notably, smart home technology was determined to be more acceptable to older adults if they were paid for by family or the government [18].

Proactive and Ongoing Ethics Analysis and Management

Overview

Consideration of ethical issues and ethical practices is increasingly viewed as core in development, evaluation, and implementation activities for assistive and rehabilitation technology, which includes smart homes [47]. Ethics is relevant to the (1) development (including conception) and implementation of smart homes to align outputs and outcomes with our ethical, social, and cultural values and (2) processes for development, evaluation, and implementation of smart homes. Existing processes entail ethical considerations that are relevant to smart homes include approvals for ethical research conduct and regulatory approvals addressing safety, effectiveness, and standards compliance for product and service transfer to market. These processes are highly focused and may not thoroughly reflect the broader questions of what we develop and implement; whether these innovations align with our values; and the ethical implications of innovations (as in 1) and how we develop, evaluate, and implement smart homes and whether our processes are consistent with these values (as in 2).

The success of smart home technology will ultimately be adoption, sustained use that facilitates health and well-being outcomes of older adults and caregivers, and increased sustainability of health and social care systems. The concepts within the 6 domains presented have been shown in research to influence adoption and use of smart homes. Smart homes may have a greater likelihood of success with committed proactive and comprehensive analysis, anticipation, and management of ethical concerns. For users with frailty, these processes need especially to reflect and accommodate their unique circumstances throughout the course of projects. Older adults with frailty may require more nuanced consideration with regard to technology use owing to their heightened vulnerability resulting from limitations in physical and cognitive abilities, experiences of mental health concerns and isolation, and reliance on others. Frailty is a complex condition necessitating management through an interdisciplinary clinical approach alongside older adults and their caregivers. This scenario leads to greater complexity in ethical analysis. Development and implementation may be enhanced through ethically aligned practices that place users and their contexts and usability goals at the center of activities such that outputs are usable and accessible by users in various living situations and market and funding systems. We emphasize ongoing analysis and management as the conditions and information related to previous decisions may change over time. A mindset that embraces potential unknowns and promotes reevaluation and course correction if circumstances change may enable better outcomes.

A lack of consideration and mitigation of ethical issues may result in several negative outcomes. Unfavorable perceptions from the public regarding technology and its potential uses and benefits may lead to the rejection of technology-based solutions or the removal of public resources for future research and development. This may result in the loss of opportunities for future implementation to benefit users. Errors or differences in understanding or expectations with AI and other technologies may result in inappropriate policies and legislation and again halt potentially important progress [41]. The adoption of appropriate measures for oversight of technology using AI requires ethical considerations and should be established before implementation and use [44]. There may be amplification of stigma and discrimination related to older people, disability, or assistive technology use, which may result in harm or unrealized opportunities. Negative perceptions of technology from poor consideration of ethical issues may result in a lack of investment from business developers who may be needed to commercialize technology or lack of funding from public funders or private insurers to support access for use [48].

Recommendations

To facilitate proactive and ongoing analysis and management of ethical concerns, we recommend collaboration among all stakeholders. This includes older adults; members of their support ecosystems; and the research, technical development, clinical, and industry communities in the field of smart home technology. This collaboration may be achieved through their inclusion in workshops and project teams. It is essential to cocreate a framework and associated resources and tools to support its implementation. The framework may include 4 elements to be discussed and elaborated on (Textbox 1).

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Conclusions

Successful adoption and sustained use of smart homes in the management of frailty in older adults have thus far been limited. Older adults with frailty require nuanced consideration when incorporating technology into their care because of their complex health and social status and vulnerability. Unmitigated ethical concerns are important factors restricting older adults and their support ecosystems from benefiting from the use of smart home technology. Applying a proactive and ongoing ethics analysis and management approach from development, evaluation, and implementation to sustained use is important for success. We recommend the development of a framework along with educational resources and analysis tools, co-created by older adults, members of their support ecosystems, and other stakeholders, to support the implementation of this approach. Within this framework, consideration of a range of conceptual domains derived from bioethics and technology ethics is key: (1) privacy and security, (2) individual and relational autonomy, (3) informed consent and supported decision-making, (4) social inclusion and isolation, (5) stigma and discrimination, and (6) equity of access. Smart homes may have a greater likelihood of accommodating users and their contexts with committed and comprehensive analysis, anticipation, and management of ethical concerns that reflect the unique circumstances of these users. Smart home technology use may then achieve its desired individual, societal, and economic outcomes and serve as a solution to support health; well-being; and responsible, high-quality care.

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Authors' Contributions

RHW conceived and designed the work and drafted and substantively revised the manuscript. TT, NB, MC, and RA conceived and substantively revised the work. All authors read and approved the final manuscript.
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References


Abbreviations

AI: artificial intelligence
Developing a Memory and Communication App for Persons Living With Dementia: An 8-Step Process

Ellen L Brown1, BSN, MS, EdD; Nicole Ruggiano2, MSW, PhD; Sai Chaithra Allala1, MS; Peter J Clarke3, BSc, MS, PhD; Debra Davis3, BA, MA, MS, PhD; Lisa Roberts1, PT, MS, DPT, CSCS; C Victoria Framil1, BSN, MSN, DNP; María Teresa Teri Hernandez Muñoz2, AA, BS, MS, SPLD; Monica Strauss Hough1, BA, MA, PhD; Michelle S Bourgeois4, BS, MS, PhD

1Nicole Wertheim College of Nursing and Health Sciences, Florida International University, Miami, FL, United States
2School of Social Work, The University of Alabama, Tuscaloosa, AL, United States
3Knight Foundation School of Computing and Information Sciences, Florida International University, Miami, FL, United States
4University of South Florida, Tampa, FL, United States

Corresponding Author:
Ellen L Brown, BSN, MS, EdD
Nicole Wertheim College of Nursing and Health Sciences
Florida International University
11200 SW 8th St
Office 226
Miami, FL, 33199
United States
Phone: 1 3053481312
Email: ebrown@fiu.edu

Abstract

According to the 2022 Alzheimer’s Association Facts and Figures, more than 6 million Americans have Alzheimer disease and related dementias. They are cared for by millions of family members, friends, or other unpaid caregivers. Communication deficits are common among persons with Alzheimer disease and related dementias and pose challenges to caregiving and clinical care, which is already complex. An interdisciplinary team developed a mobile app prototype to improve communications between people living with dementia and their caregivers and providers and to promote person-centered care. This viewpoint paper provides a road map for how the interdisciplinary team worked together to develop and plan for the implementation and evaluation of a new evidence-based app. In our paper, we provide an 8-step process used by a team of clinicians, researchers, and software engineers to develop a new app to meet the needs of people living with dementia and their caregiver(s). The planned clinical trial has been registered at ClinicalTrials.gov (NCT04571502; https://clinicaltrials.gov/ct2/show/NCT04571502).

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KEYWORDS
health technology; interdisciplinary team; older adults; dementia; communication; communication aids for disabled persons; communication boards; app; Alzheimer disease; family; caregiver; clinical care; development; speech; psychosocial intervention; software design

Introduction

Background

People living with dementia often experience communication deficits due to a variety of symptoms associated with Alzheimer disease and related dementias, including memory loss, primary progressive aphasia, decreased attention span, and word-retrieval anomia [1-6]. These deficits can have a negative impact on caregiving and clinical care for people living with dementia while also resulting in negative physical and mental health outcomes for their caregivers [6-8].

Prior research has found that augmentative and alternative communication (AAC) devices can effectively support people living with dementia in communicating [9]. However, many of these AAC devices are limited in their ability to customize content and have been criticized for their limitations in...
addressing the personhood of people living with dementia and targeting the family as a unit in communication support [9,10]. Specifically, most of these technology-based devices are not designed to support people living with dementia in communicating their daily and changing preferences and needs [9-19]. This paper describes the first phase of a clinical trial, where a team of interdisciplinary researchers applied a multistep framework for user interface (UI) development [20] to develop an electronic AAC device, the My Person Assisted Touchscreen Interface (My PATI) for people living with dementia.

The My PATI for People Living With Dementia

The focus of this overall project was to develop an electronic AAC device for people living with dementia that aims to (1) support them in communicating their daily care preferences and needs with caregivers; (2) communicate their everyday experiences and behaviors with caregivers; (3) share information about these experiences and behaviors with providers involved with their care; and (4) provide the caregivers with the ability to easily update information, with internet access.

The newly developed My PATI provides structure and prompts and serves as a tool for ongoing engagement between people living with dementia and their caregivers. Similar to traditional paper AAC devices, My PATI uses graphic images and text that people living with dementia can point to when trying to communicate. Unlike traditional AAC devices, these graphic images can be customized. For example, rather than a generic icon of a shirt or dress, My PATI can be populated with images of the care recipient’s actual clothing to make My PATI more relevant to the person living with dementia when communicating about getting dressed for the day (see an example in Figure 1).

It also differs from traditional AAC devices in that its features are organized by activities of daily living (ADL; ie, basic self-care tasks, such as eating and grooming) and instrumental ADL (IADL; ie, more complex activities, such as preparing meals and maintaining schedules). My PATI is designed to support the autonomy and life participation of people living with dementia, by allowing them to make selections about their care preferences during ADL and IADL throughout the day. For example, My PATI provides personalized touchscreen selection options for grooming and dressing (ie, ADL) and prompts the user to communicate, manage, and engage in their surroundings (ie, IADL). The people living with dementia can use My PATI alone (when able to) or in partnership with a family caregiver, another family member, or a paid caregiver involved with their care.

My PATI has features that allow the caregiver to continually update content as the care recipient’s needs and preferences evolve, which is not easily done with a paper version of an AAC device. The caregiver UI of My PATI is designed to allow the caregiver to upload, add, or change graphics and functions that reflect the care recipient’s unique preferences and memorabilia. For example, images of clothing may be updated to reflect a change in the season, or a change of diet may necessitate the need for different food choices. This feature of updating graphic images and the ability to access the app from anywhere with internet connectivity is novel. Textbox 1 features the fictitious case of Mary, an older adult with dementia, demonstrating an example of the potential use of My PATI. Figure 1 provides a screenshot from My PATI, displaying options Mary is offered regarding her breakfast preferences and what she would like to wear.

Figure 1. Screenshots of Mary’s preferences for breakfast and clothes. My PATI: My Person Assisted Touchscreen Interface.
My PATI is grounded in evidence from low-technology versions of AAC devices [21]. In the mid-1980s, when dementia was a new diagnosis, there were no known interventions for its accompanying memory and communication problems. Bourgeois [22] developed the Memory Wallet, a collection of 30 pages of personal information, one photograph per page captioned with a 5- to 7-word declarative sentence, to provide prompts for desired conversation topics. Persons with midstage dementia used the wallets to read the sentence and comment about the photograph, increasing the overall number of on-topic statements made during conversations with the wallet compared to those without the wallet; they also decreased the number of ambiguous, repetitive, and erroneous utterances made during conversations with the wallet. In the following years, Bourgeois [23] systematically replicated the effects of the 1990 study with individuals across the continuum of dementia severity using various sizes of memory books and demonstrated similarly positive effects, as long as the size of the font was large enough to be read easily, and the content of the pages was personally relevant. Caregivers reported serendipitous effects of the memory aids on other challenging behaviors, including the reduction of repetitive questioning when the person was shown the page in the aid that answered the question [22-24]. The effects of memory aids were also evaluated in conversations and care interactions between people living with dementia and nursing aides [25-27] and spousal caregivers [28,29]. The overall conclusion of these studies was that reading is believed to be an overlearned behavior and a preserved skill and that personalized text has the potential to moderate the effects of memory loss [30]. Therefore, My PATI features incorporate individualized text and content to support meaningful engagement for the person living with dementia and their caregiver [31].

From the perspective of a speech-language pathologist, MY PATI clearly provides an approach to treatment that is rehabilitative in nature. Communication rehabilitation for people living with dementia encompasses all treatments geared toward providing the client with the skills or access to strategies that will assist them to regain or compensate for what has been disrupted [32,33]. A major objective of MY PATI was to compensate for communication functions to the greatest extent possible about daily preferences. This is instrumental for facilitating person-centered care (PCC) for people living with dementia. PCC in dementia care stems from the groundbreaking work of Kitwood [31]. Dementia Reconsidered the First Comes First, which asserts that people living with dementia need to be involved in decision-making about their care whenever possible. It also posits that care for people living with dementia should emphasize their preferred needs, values, and life history. This is facilitated by knowing the person receiving care, which requires interpersonal relationship and communication between people living with dementia and their care providers [34-36].

As PCC has become the gold standard of care, an increasing number of technologies that support the autonomy of people living with dementia have emerged, including monitoring technologies for the safety of people living with dementia, robotics, therapeutic technologies, and various apps to support brain and mental health [37]. Hence, My PATI is part of a larger trend in IT to support this population. Unfortunately, there currently lacks a consensus on standards or guidelines for delivering PCC to inform technology development [34-37]. However, the development of My PATI has been informed by the definitions and conclusions reported by the American Geriatrics Society Expert Panel on PCC [36].

**An 8-Step Process for Developing My PATI**

**Overview**

Moving from the traditional paper format of an AAC device or memory aid for people living with dementia to an electronic version requires experts from multiple disciplines, including nursing, social work, physical therapy, speech therapy, and software engineering. Interdisciplinary development teams can sometimes encounter challenges when health and social scientists collaborate with engineers. For example, health and social scientists may not understand the capabilities or limitations of technologies, and engineering members may not understand the context of health and social problems being addressed. There are no easy answers on how to address these barriers. Still, an agreed-upon stepwise process that allows for regular opportunities for groups to talk about issues and share progress is helpful.

To develop My PATI, our team developed and implemented an 8-step process (see Figure 2). The diagram provides a proposed communication flow for information throughout the 8 steps. The ongoing communication between the software engineers and the clinical and research team members was critical. This was a challenge as this development work was primarily done remotely during the COVID-19 pandemic. Ongoing communication occurred primarily with the use of web-based meetings, emails, and phone calls. Additionally, in-person interactions with research subjects were not permitted for a
period of time due to the pandemic, which posed challenges for obtaining feedback from potential end users. Web-based focus groups and interviews were used. Beginning in the next section of this paper, we describe our multistep process that has been implemented to develop and evaluate My PATI.

The underlying principle for developing My PATI in steps 1 through 4 in Figure 2 is based on 3 software process models. These models included the incremental, throwaway prototype, and agile (a combination of incremental and prototyping, see Textbox 2 for definitions) models [38,39]. My PATI is a research app, thus making the requirements, by definition, inherently vague. Further adding complexity to the development process is the fact that the research team is highly interdisciplinary. The overall approach to developing the app involved first defining the software requirements using a throwaway prototype, then applying an agile approach to implement the app based on the requirements produced by the team. The throwaway prototype was critical to getting the UI correct before any implementation activities of the app starts. The agile approach (see Textbox 2) was the most suitable for the implementation stage since the health care experts and potential users (ie, customers) were frequently consulted during the implementation of My PATI. The approach we used for the project is supported by Dawson and Dawson [39], based on their analysis of various software process models using functionality-time graphs and combined functionality-time/cost/benefit graphs.

**Figure 2.** Multistep process used to develop and evaluate My Person Assisted Touchscreen Interface (My PATI).

**Textbox 2.** Software engineering definitions.

- An **incremental software model** produces successive increments of working, deliverable software based on partitioning of the software requirements to be implemented in each of the increments [40].

- **Software prototyping** is an activity that generally creates incomplete or minimally functional versions of a software application, usually for trying out specific new features, soliciting feedback on software requirements or user interfaces, further exploring software requirements, or gaining some other useful insight into the software [40].

- **Agile software methods** are considered lightweight methods in that they are characterized by short, iterative development cycles; frequent customer (ie, health care experts and potential users) involvement; and an emphasis on creating a demonstrable working product with each development cycle [40].
Step 1: Identification of My PATI Requirements by Clinical Experts

The development and decisions regarding My PATI app features were guided primarily by the work of Bourgeois and theories on PCC, as described earlier. Early in the process, a goal of the social scientist members of the team was to provide the software engineering team with a background in PCC. This was essential as the common understanding of the challenges and strategies for promoting evidence-based PCC provides a road map and common language for our work. The engineering team was provided with articles and related videos to assist them in developing a greater understanding of the uniqueness and routine daily needs of people living with dementia. Clinical team members provided insights into functional and cognitive impairments that provided the foundation for My PATI features and navigation based on their experiences with patients and families. The decision to use touchscreen technology was evidence based, as touchscreens are the optimal mechanism for delivering My PATI to people living with dementia. The use of touchscreen technology by people living with dementia has been the focus of 2 systematic reviews [16,17], which established that people living with dementia can use personalized touchscreen technology independently and engage with touchscreen technology to improve interactions, supporting relationships and fostering PCC.

Step 2: Requirements Interpreted by the Software Engineers

The design of the My PATI prototype incorporated a goal-directed and user-driven design process. In this approach, the main focus of planning and developing the system was on the goals and needs of the primary user population for each functional component or interface of the system. This resulted in providing enhanced usability and ubiquitous user experiences (UXs) for the targeted users [41]. The UI/UX experts on the software engineering team began this process by working closely with the entire team, assessing the purpose, scope, and goals for creation of the My PATI design. It was determined that there were 2 functional components of the system, namely (1) the capabilities of people living with dementia for communicating their preferences and feelings about their daily care activities and experiences; and (2) the capabilities of caregivers for set-up and the available customization functions of the app.

For the more detailed design, the UX experts incorporated UX design best practices, including conducting in-depth formative and substantive UX research throughout the development process [20]. For the UX research, the clinical experts of people living with dementia were the participants of the studies. This was important as it is the clinical experts who are the most knowledgeable about the primary users of the interface for people living with dementia, particularly their special cognitive and functional needs. UX research included contextual inquiries using a think-aloud protocol, clinical expert focus groups, persona and scenario creation, user case studies, and workflow analysis. The design and development studies were conducted separately with the clinical experts, caregivers, and people living with dementia. The methodologies used included participatory design using paper prototyping, wireframing and interactive prototyping, heuristic evaluation, and usability testing.

Step 3: Engineers Built a Prototype

As described above, the software engineering team built the prototype using the requirements provided by the health care experts and interpreted by the UI/UX experts. The requirements were captured using structured natural language as use cases. The My PATI prototype was built using Axure [42]. Axure is a wireframing and prototyping tool that allows UI/UX designers to quickly create interactive interfaces for an app without writing a line of program code. Figure 2 shows the cycle used to develop the My PATI prototype, which involved steps 1, 2, 3, and 4 in the cycle. The software engineering team developed at least five versions of the prototype, with the health care and UI/UX experts reviewing each version and providing feedback to the engineering team. These versions are shown in the box labeled “Version of My PATI” between steps 3 and 4 and were built using the best practices in UI/UX development [20]. The first and last versions of the My PATI prototype are shown in Figure 2. Additional screenshots of My PATI are shown in Figure 1, showing how Mary and her caregiver are able to select her daily activities, such as what Mary would like for breakfast and what she would like to wear for the day.

Step 4: Prototype Evaluated by Clinical Experts Followed by Repeating Steps 1-4

The research team then had the clinical experts review the prototype. It was initially determined that the graphic icons used for the app may not adequately reflect the feature or function that the icon represented (eg, music library and video library). The research team then consulted with an artist with UI/UX experience. The clinical team then engaged in a series of meetings with the artist to provide their clinical input about the various aspects of the icon (eg, the significance of the icon and its appropriateness for people living with dementia). The artist then redesigned the icons, which were integrated into the prototype. When this process was complete, the team continued steps 1 through 4 until consensus was reached on icon design.

Step 5: User Study Conducted With a Person Living With Dementia and a Caregiver

User studies with both people living with dementia and caregivers have been conducted following approval from an Institutional Review Board (IRB-21-0527). For potential end user feedback, we implemented a participatory research design with persons with moderate cognitive impairment (defined as a recent Montreal Cognitive Assessment score of 10–17 or Mini-Mental State Exam score of 13–20) and caregivers at a collaborating memory clinic. The provided data revealed potential navigation issues, and our team made modifications to simplify navigation based on these findings. The protocol was structured and developed jointly by clinicians, researchers, and software engineers, and interviews were audio recorded. During the interview of the person living with dementia, we evaluated if the My PATI app’s features could be accessed by the participant without difficulty. Finally, we validated whether the participant’s selections were valid and reflected the true preference of the person living with dementia (as opposed to...
random touches on the screen). The team worked together to develop a methodology to gain insight into the validity of the person’s true preference. Our approach was to compare the selected iPad choice (in the My PATI app) to the actual item. See Textbox 3 for an example of how the protocol validated respondent food choice.

To date, for these participants, there was agreement between the snack choice made with the My PATI interface and the snack choice made when the person living with dementia was presented with the actual snack by the interviewer. There was agreement for the majority of validation tests. More data from more participants are needed and are planned. To date, 5 participants—3 caregivers and 2 people living with dementia—have been able to navigate through the app and perform tasks with ongoing guidance and support. A barrier to this usability testing has been that the information in the current My PATI prototype is not “personalized” (eg, generic pictures of food, clothing, and activities). A pilot is planned to test My PATI with personalized information (step 7).

Textbox 3. Instructions on the interview protocol for user study.

Interviewer: “Now I am going to ask you about things you ordinarily like to eat and drink.”
- Show the person living with dementia the 2 snack options, pointing to each but not touching the iPad.

Interviewer: “What do you ordinarily like to eat?”
- Hold the iPad while the participant selects their choice or if the participant verbally states their response, select their response for them. Once a selection is made, put the iPad down and bring out the physical snacks (ie, identical to images on the iPad) while stating the following.

Interviewer: “I have a couple of snacks. Which of these snacks do you prefer?”
- Document the selected snack.

Step 6: Results Interpreted by Experts and Updated

This step is similar to step 4, where the clinical experts will review the results from the user study and make recommendations for interface revision (if deemed necessary), which would be followed by steps 1-4 again.

Step 7: My PATI Pilot Implementation

A small pilot will be conducted in preparation for the planned clinical trial (see step 8). These findings will be used to make necessary changes to My PATI and inform the design of a subsequent clinical trial (step 8). The team recognized from previous research [43-46] that the implementation and use of an app can present challenges. As a component of implementation, a decision was made that materials are needed to both educate the participants on technology and guide them in the use of My PATI; these materials will be evaluated in the pilot. Central to these implementation materials will be audiovisual presentations (available on the web) for the My PATI app described below. A decision was made, based on our previous research [44,46], that the technology needs to be seamlessly integrated into daily life, or it will not be viewed as helpful and be underused. It is for this reason that the “A Day in the Life with My PATI” implementation video is being developed. Textbox 4 provides a condensed version of the script from the video, which portrays a common daily interaction between Grandma Mary (person living with dementia) and Samantha (her granddaughter).

Textbox 4. Condensed script excerpt from the My Person Assisted Touchscreen Interface (My PATI) implementation video.

Samantha: “Good Morning, Grandma. How are you feeling today?”
Grandma Mary: (smiles at Samantha)
Samantha: “Grandma, we have a doctor’s appointment later this morning. What would you like to wear today?”
- Samantha shows Mary photos of her clothes displayed on My PATI. Mary looks over her choices and touches the icons on the screen picturing her pink blouse and white slacks.

Samantha: “Nice choice, Grandma! You will look very pretty for the doctor. Let’s get ready.”
- Samantha helps her grandmother stand up, and they move off together to get dressed.

Step 8: Conduct a Clinical Trial of My PATI

A trial is planned to commence in the spring of 2024 with triads of people living with dementia, caregivers, and their health care providers [47,48]. The study will investigate the impact of using My PATI on a number of outcomes. Two clinical sites (Miami, Florida, and Birmingham, Alabama) are collaborators for the project, and the study will enroll 60 triads at each site. The trial consists of 2 arms, where participants in both arms will continue receiving regular health care services at their respective clinics. Participants in the treatment (My PATI) group will receive training on how to use the device and then be asked to use the device as part of their regular daily caregiving routine for a period of 12 months. Outcome measures will be assessed at baseline, 6 months, and 12 months over the phone. Primary outcome variables include improving the quality of life for people living with dementia and their caregiver. Secondary outcome measures include depression, positive aspects of...
caregiving, caregiver burden, and overall health for the caregiver; depression, memory, and behavioral problems; functional linguistic communication for people living with dementia; engagement of people living with dementia and their caregivers; and provider perceptions of the intervention. All user data for My PATI by all participants will be tracked and analyzed. Full details about the outcome variable measures to be used and the research design can be accessed at ClinicalTrials.gov (NCT04571502). Results are anticipated to be available in 2025.

Limitations

There are several limitations of the 8-step approach presented in this paper and adjustments that should be made if the process was repeated. First, most the team had previously worked together on the development and testing of another dementia caregiver app before developing My PATI [44]. It is suspected that clinical and engineering teams working together for the first time would need more time to progress through the early stages of the 8-stage process. Second, due to the COVID-19 pandemic, our development process included limited collaboration with people living with dementia and their caregivers. Ideally, collaboration with these stakeholders would occur from the outset and for as often as needed. It should be noted that multiple members of the research team had experience with caregiving for someone living with dementia, concurrently or previously. These experiences were often included in the team discussions.

Conclusions

This paper provides a road map for implementing an interprofessional practice approach to developing an evidence-based app, My PATI, designed for older adults diagnosed with dementia and their caregivers. An interdisciplinary team of clinicians, researchers, and software engineers collaborated to develop My PATI to improve the quality of life of a person diagnosed with dementia by increasing their independence and participation. My PATI’s 8-step developmental process is described along with hypothetical scenarios demonstrating its use. The authors of this paper are planning to initiate the trial in the winter of 2024. This study will investigate the effectiveness of using My PATI in improving the quality of life of people with Alzheimer disease and related dementias and their caregivers. The results of this study are anticipated to be available in 2025.

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Conflicts of Interest

None declared.

References


42. Axure RP 10. Axure Software Solutions. 2012. URL: https://www.axure.com/ [accessed 2023-03-06]

Abbreviations

- AAC: augmentative and alternative communication
- ADL: activities of daily living
- IADL: instrumental activities of daily living
- My PATI: My Person Assisted Technology Interface
- PCC: person-centered care
- UX: user experience
- UI: user interface

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Contextual Factors That Impact the Implementation of Patient Portals With a Focus on Older People in Acute Care Hospitals: Scoping Review

Zarnie Khadjesari1*, PhD; Julie Houghton1*, MA; Tracey J Brown2, MSci; Helena Jopling3, MBBS; Fiona Stevenson4, PhD; Jennifer Lynch5, PhD

1Behavioural and Implementation Science research group, School of Health Sciences, University of East Anglia, Norwich, United Kingdom
2Norwich Medical School, University of East Anglia, Norwich, United Kingdom
3Department of Public Health, West Suffolk NHS Foundation Trust, Bury St Edmunds, United Kingdom
4Department of Primary Care and Population Health, University College London, London, United Kingdom
5School of Health and Social Work, University of Hertfordshire, Hatfield, United Kingdom
* these authors contributed equally

Corresponding Author:
Zarnie Khadjesari, PhD
Behavioural and Implementation Science research group
School of Health Sciences
University of East Anglia
Norwich Research Park
Norwich, NR4 7TJ
United Kingdom
Phone: 44 01603 597001
Email: Z.Khadjesari@uea.ac.uk

Abstract

Background: Older people are the highest users of health services but are less likely to use a patient portal than younger people.

Objective: This scoping review aimed to identify and synthesize the literature on contextual factors that impact the implementation of patient portals in acute care hospitals and among older people.

Methods: A scoping review was conducted according to the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines. The following databases were searched from 2010 to June 2020: MEDLINE and Embase via the Ovid platform, CINAHL and PsycINFO via the EBSCO platform, and the Cochrane Library. Eligible reviews were published in English; focused on the implementation of tethered patient portals; included patients, healthcare professionals, managers, and budget holders; and aimed at identifying the contextual factors (ie, barriers and facilitators) that impact the implementation of patient portals. Review titles and abstracts and full-text publications were screened in duplicate. The study characteristics were charted by one author and checked for accuracy by a second author. The NASSS (Non-adoption, Abandonment, Scale-up, Spread, and Sustainability) framework was used to synthesize the findings.

Results: In total, 10 systematic reviews published between 2015 and 2020 were included in the study. Of these, 3 (30%) reviews addressed patient portals in acute care hospitals, and 2 (20%) reviews addressed the implementation of patient portals among older people in multiple settings (including acute care hospitals). To maximize the inclusion of the literature on patient portal implementation, we also included 5 reviews of systematic reviews that examined patient portals in multiple care settings (including acute care hospitals). Contextual factors influencing patient portal implementation tended to cluster in specific NASSS domains, namely the condition, technology, and value proposition. Certain aspects within these domains received more coverage than others, such as sociocultural factors and comorbidities, the usability and functionality aspects of the technology, and the demand-side value. There are gaps in the literature pertinent to the consideration of the provision of patient portals for older people in acute care hospitals, including the lack of consideration of the diversity of older adults and their needs, the question of interoperability between systems (likely to be important where care involves multiple services), the involvement of lay caregivers, and looking beyond short-term implementation to ways in which portal use can be sustained.
Conclusions: We identified important contextual factors that impact patient portal implementation and key gaps in the literature. Future research should focus on evaluating strategies that address disparities in use and promote engagement with patient portals among older people in acute care settings.

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KEYWORDS

patient portal; tethered personal health records; acute care hospitals; implementation; scoping review

Introduction

Background

Patient portals (also known as tethered personal health records) consist of an internet-based application that accesses the electronic health record of a health care organization and provides timely access to medical records, laboratory results, appointment bookings, repeat prescriptions, and secure messaging with health care professionals, among other content and functionality [1]. Patient portals aim to engage patients and carers in managing their care, which has been found to improve health outcomes, the quality of care, and patient safety [2]. Patient portals are well established in UK family practice, with electronic health records being commonplace in 96% of general practices for almost 3 decades [3]. In UK acute care hospitals, the use of handwritten inpatient records remains widespread [3], and as such, patient portals are less common. Global Digital Exemplar (GDE) trusts are internationally recognized providers of exceptional and efficient National Health Service (NHS) care via world-class digital technology and information and are committed to sharing best practices and supporting the widespread adoption of patient portals [4]. The future vision of the NHS is to create a single access point to acute care hospitals with integrated systems that share and exchange data securely with other health and care providers [5]. However, the integration of portals with the existing systems is currently a barrier to their adoption, in addition to clinical engagement, information governance, low patient awareness, and resources [6]. Furthermore, among the patients who currently access portals, engagement or meaningful use is often limited.

The greatest benefit to patients and the health service can be achieved by optimizing portal use among older people [7]. Older people (aged ≥65 years) are less likely to use a patient portal than younger people (86% of adopters are aged <65 years) [8], yet they are the highest users of the health service, with more than half (54%) of them experiencing multimorbidity [9]. Older people are more at risk of serious complications and hospital-acquired infections, and they may experience frailty and other mobility problems that hinder their access to health centers. Moreover, older age is the greatest risk factor for mortality from COVID-19 [10]. Barriers are exacerbated when older patients lack access to and experience of using technology, have lower levels of education, and have low health literacy [11-13]. However, older people have been found to express interest in using a patient portal independently or with a carer, irrespective of their health literacy level, previous portal use, or experience seeking health information over the internet [11]. The COVID-19 pandemic has accelerated the rate of adoption of digital technologies in health care settings by necessitating remote visits, communication, and monitoring, which are especially important for people managing long-term health conditions [14]. The need and demand for more flexible access to health services are unlikely to diminish.

There are numerous reviews of patient portal features, functionality, adoption, and implementation, with the vast majority focusing on family practice settings. A review examining portal use in multiple health care settings was published by Antonio et al [14]. This umbrella review explored the current state of evidence for patient portals, with a specific focus on portal technology. It identified several factors that influence portal adoption, including patient circumstances, interest, and satisfaction; portal usability; provider attitudes; and service use [14]. Another review across multiple health care settings reported a range of patient characteristics that impact portal use, such as age, ethnicity, education, health literacy, health status, and carer role [7], and factors that impact patient portal engagement, such as provider endorsement and portal usability. The authors argue that future research should aim to boost portal engagement among specific populations most likely to benefit from its use [7]. This review set out to scope the literature on older people and acute care settings to inform the broader aim of our research program—to develop an evidence-based implementation strategy for portal use and engagement among older people in acute care settings. Despite efforts toward the widespread uptake of and engagement with patient portals across acute NHS trusts, there is limited research into evidence-based strategies for successful engagement [15]. Engagement strategies, such as advertisement campaigns or training for patients, carers, and staff, must be tailored to the targeted population groups and the local context to be effective [16]. Tailoring can improve equity within the patient group. Identifying contextual factors that impact the routine implementation of patient portals in acute care hospitals is the first step toward developing an evidence-based implementation strategy for older people.

Aim

The aim of this scoping review was to identify and synthesize the literature on contextual factors that impact the implementation of patient portals in acute care hospitals and among older people.

Our primary interest was to improve the engagement with patient portals among older people in acute care hospitals. However, we needed a broad scope of the literature to capture learning from studies in multiple settings (family practice and acute care hospitals) and patient groups (general population and older people), given the potential generalizability of the findings across settings.
Methods

Reporting Guidance and Theoretical Framework

This scoping review followed the methodological framework described by Arksey and O’Malley [17] and the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) reporting guidelines [18]. The framework was selected to achieve our broad aim of summarizing what is known about our primary area of interest, to synthesize findings, and to highlight key gaps in the literature.

Non-adoption, Abandonment, Scale-up, Spread, and Sustainability Framework

To build on the existing literature, we used a theoretical framework to provide a semantic structure to the synthesis of our findings. The NASSS (Non-adoption, Abandonment, Scale-up, Spread, and Sustainability) framework [19] provided the basis for summarizing the results. This framework was developed to analyze the varied outcomes of technological innovations in health and social care and to help inform the implementation of such technologies. The NASSS framework comprises 7 domains: (1) the condition or illness, (2) the technology, (3) the value proposition, (4) the adopter system (intended users), (5) the organization, (6) the wider system (especially regulatory, legal, and policy issues), and (7) a final cross-cutting domain that considers adaptation and embedding over time. Each of the 7 domains can be “simple” (ie, few components and predictable), “complicated” (ie, many components but still largely predictable), or “complex” (ie, many components interacting in a dynamic and unpredictable way). Crucially, NASSS surfaces factors that are often unacknowledged in technology implementation programs, helping to move beyond the identification of individual barriers and enablers in recognition of the dynamic interactions between the domains, for example, the relationship between the individual adopter and the organizational or wider system context.

Search Strategy

A search strategy was developed in collaboration with an academic librarian. As a preliminary examination of the literature indicated that only a few reviews focused solely on acute care hospitals or older adults and because the specific health care setting was not always immediately clear, we decided not to include filters for population or health care setting in order not to exclude potentially relevant publications.

The full search strategy is shown in Textbox 1. Search terms related to patient portals and systematic reviews were used. The search strategy used a combination of medical subject headings and free-text words. Searches were restricted to 2010 to account for the pace of development in portal technology. Searches were conducted on June 16, 2020, and included the following databases: MEDLINE and Embase via the Ovid platform, CINAHL and PsycINFO via the EBSCO platform, and the Cochrane Library. Reference lists of the included reviews were screened for additional literature.

To generate sufficient breadth of coverage for the scoping review, inclusion criteria were defined to capture maximum learning with respect to the implementation of tethered patient portals among older people and in acute care hospitals. Specifically, 3 categories of reviews were eligible for consideration:

1. Systematic reviews of patient portals in acute care hospitals
2. Systematic reviews of reviews (with both primary studies and reviews) of patient portals in multiple settings, including acute care hospitals
3. Systematic reviews of patient portals for older adults in multiple settings, including acute care hospitals

The inclusion criteria were as follows: reviews published since 2010 in English; reviews focused on the implementation of tethered patient portals (as defined in the Introduction section); reviews focused on patient portals for older adults (in settings that include acute care hospitals); reviews focused on patient portals for patients, health care professionals, managers, and budget holders in acute care hospitals; reviews of reviews of patient portals in settings that include acute care hospitals; reviews focused on contextual factors (ie, barriers and facilitators) that impact the implementation of patient portals; systematic reviews; scoping reviews; narrative reviews; qualitative meta-syntheses; meta-ethnographies; and reviews of reviews.

The exclusion criteria were as follows: reviews published before 2010; reviews not in English; reviews not focused on the implementation of tethered patient portals; reviews focused on the technical aspects of patient portals; reviews in family practice settings only; nonsystematic reviews; secondary analyses of the existing data sets; discussions of literature for theory building or critique; summaries of literature for information or commentary; editors’ discussions; letters; conference abstracts; and theses; and reviews whose full text was not available.
**Textbox 1.** Search strategy by database.

**Search terms for MEDLINE and Embase (via OVID)**

1. Exp Patient Portals/
2. Health Records, Personal
3. Patient ADJ2 Portal*.mp
4. Electronic ADJ2 Portal.mp
5. (personal adj2 (health or medical) adj2 (record* or info*)).mp
6. Patient accessible record*.mp
7. PHR.mp
8. ePHR.mp
9. or/1-8 (MEDLINE) or/3-8 (EMBASE)
10. Meta analysis/
13. Review.ti,ab,pt.
14. or/10-13
15. and/9,14
16. Limits – English Language, 2010-current, humans

**Search terms for CINAHL and PsycINFO (via EBSCO)**

1. MH “Patient Portals”
2. MH “Medical Records, Personal”
3. Patient n2 Portal*
4. Electronic n2 Portal
5. Personal n2 (health or medical) n2 (record* or info*)
6. Patient accessible record*
7. PHR
8. ePHR
9. or/1-8 (CINAHL) or/3-8 (PsycInfo)
10. MH Meta analysis
11. Meta-analysis
12. Meta-ethno*
13. Review.ti,ab,pt.
14. or/10-13
15. and/9,14
16. Limits – English Language, 2010-current

**Search terms for Cochrane Library**

1. Exp Patient Portals
2. Health Records, Personal
3. Health Records, Electronic

---

**Study Selection**

Search results were imported into EndNote reference management software (Clarivate Analytics), and duplicates were removed automatically and double checked manually. Two reviewers (JH and ZK) independently screened titles and abstracts. Any discrepancies in the articles identified for full-text screening were discussed, and consensus was reached. Full-text
articles of potentially eligible reviews were assessed independently by 2 reviewers (JH and ZK) against the prespecified inclusion and exclusion criteria. Discrepancies were resolved through discussion. The reasons for exclusion were recorded and included in the PRISMA diagram (Figure 1).

**Figure 1.** PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram.

**Data Charting**

In accordance with the Arksey and O’Malley framework for scoping reviews [17], a data charting form was compiled in Microsoft Excel (Microsoft Corp), which contained a row for each included study and columns to record general study information, namely authors, publication date, country of origin, review aim, health care setting, participants, definition of patient portal, theoretical framework, database searches, inclusion and exclusion criteria, data extraction method, quality assessment method, method of analysis or synthesis, and the number of included studies. The included studies were examined to determine the extent of study overlap between the included reviews. The data charting form was also used to extract data on the contextual factors (barriers and facilitators) that impacted the implementation of patient portals in accordance with the 7 domains of the NASSS framework (refer to the NASSS Framework section), together with the authors’ recommendations for future research. The form was piloted on 4 studies. A single reviewer (JH) read each study and extracted the study characteristics and data on contextual factors from the results and discussion sections. The discussion sections were included in the charting process, as they often provide additional material to enhance the interpretation of review findings. The data extraction for each of the 4 articles was cross-checked by another team member (TJB, ZK, JL, and FS) to verify whether data charting was performed in accordance with the 7 NASSS framework domains. Data charting was then completed by a single reviewer (JH) and independently verified by another member of the team (ZK).

**Summarizing the Results**

A narrative approach was used to summarize the results of the scoping review. In line with the usual practice for scoping reviews [17], no attempt was made to assess the quality of the included reviews or the weight of the evidence with respect to the implementation of patient portals.

**Results**

**Search Results**

A total of 2065 references were identified (Figure 1). After the removal of duplicates (n=606, 29.35%), another 1340 (64.9%) records were excluded based on the title and abstract, leaving 119 (5.76%) full-text articles to be assessed for eligibility. Of the 119 full papers assessed, 10 (8.4%) met the criteria for inclusion in this scoping review. Scrutiny of the reference lists of the included reviews did not generate additional literature for inclusion. Multimedia Appendix 1 provides details on the characteristics of the included reviews [15,20-28].

**Description of the Included Reviews**

The reviews were published between 2015 and 2020. Of the 10 included reviews, 4 (40%) originated from the United States [15,20-22], 2 (20%) each from the United Kingdom [23,24] and the Netherlands [25,26], and 1 (10%) each from Australia [27].
and Iran [28]. Overall, 3 (30%) systematic reviews addressed patient portals in acute care hospitals [15,20,23], 5 (50%) systematic reviews of reviews examined patient portals in both acute care hospitals and other care settings [24-27,28], and 2 (20%) systematic reviews addressed the implementation of patient portals among older adults (in multiple settings, including acute care hospitals) [21,22].

Of the included reviews, 7 (70%) did not specify a particular framework for the analysis of the results [20-24,27,28], 1 (10%) used the System Engineering Initiative for Patient Safety model to categorize interventions [15], 1 (10%) used the Clinical Adoption Framework [25], and 1 (10%) applied the Problem Solving Cycle [26]. Reviews in which no framework was specified considered portal design, use, and usability [20]; input, process, and output factors [27]; content and capabilities [28]; impact on outcome measures [24]; barriers to and facilitators of adoption and user experience [21]; characteristics of older users, evaluation of outcome measures and results, and barriers to and facilitators of use [22]; and impact on trust and communication and consideration of ethical issues [23].

Study Overlap

To establish the breadth of coverage of this scoping review, an indication of the extent of overlap of studies in the included reviews was determined. The included reviews contained 206 studies (156 primary studies, 75.8%, and 50 reviews, 24.3%), excluding the 109 references of Otte-Trojel et al [26], which, unfortunately, we were not able to obtain for scrutiny. Table 1 provides a summary of the extent of study overlap. Only 19 studies appeared in >1 included review, suggesting limited duplication in the scoping review.

### Table 1. Overlap of studies.

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Acute care hospitals, n</td>
<td>0/N/A</td>
<td>0/3</td>
<td>3/0</td>
<td>0/N/A</td>
<td>0/6</td>
<td>0/N/A</td>
<td>0/N/A</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>Multiple settings (review of reviews), n</td>
<td>0/N/A</td>
<td>0/1</td>
<td>1/0</td>
<td>0/N/A</td>
<td>0/6</td>
<td>0/N/A</td>
<td>0/N/A</td>
<td>0/2</td>
<td>0/2</td>
</tr>
<tr>
<td>Older adults (aged &gt;60 years), n</td>
<td>0/0</td>
<td>0/0</td>
<td>0/6</td>
<td>0/N/A</td>
<td>0/N/A</td>
<td>0/N/A</td>
<td>0/N/A</td>
<td>0/N/A</td>
<td>0/N/A</td>
</tr>
</tbody>
</table>

*Overlap tracked in 156 primary studies and 50 reviews.

*N/A: not applicable.

*Not able to obtain reference list.

Narrative of Results by NASSS Framework Domains

**Overview**

The results and discussion sections of the included studies were successfully mapped to the NASSS framework domains and subdomains. The findings for each domain are presented and a summary is provided in Table 2. The headings for the domains and subdomains are taken directly from the NASSS framework. Although each domain is commented on in turn, there are interrelationships between the findings that are highlighted in the text and addressed at the end of this section.
Table 2. Non-adoption, Abandonment, Scale-up, Spread, and Sustainability (NASSS) framework: contextual factors that influence the implementation of patient portals.

<table>
<thead>
<tr>
<th>NASSS domain and subdomain and contextual factors (namely, facilitators and barriers)</th>
<th>Acute care hospitals</th>
<th>Mixed health care setting</th>
<th>Older adults (aged &gt;60 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Condition</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>What is the nature of the condition or illness?</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater disease severity</td>
<td>—a</td>
<td>[24]</td>
<td>—</td>
</tr>
<tr>
<td>Chronic disease (and associated well-established case management programs)</td>
<td>—</td>
<td>[21,23]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity and circumstances of illness (eg, reduced involvement in decision-making and fewer questions)</td>
<td>[20]</td>
<td>[24]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Relevant sociocultural factors and comorbidities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher socioeconomic status, female sex, younger age, White ethnicity, and younger senior citizens</td>
<td>—</td>
<td>[23,24]</td>
<td>[18]</td>
</tr>
<tr>
<td>Disease-specific portal</td>
<td>—</td>
<td>[24]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower socioeconomic status, male gender, older age, and non-White ethnicity (impacts enrollment and engagement)</td>
<td>[12,20]</td>
<td>[24]</td>
<td>—</td>
</tr>
<tr>
<td>Diversity of older adults (not well understood)</td>
<td>—</td>
<td>—</td>
<td>[19]</td>
</tr>
<tr>
<td>Low health literacy and numeracy (and understanding of health literacy)</td>
<td>—</td>
<td>[23,24]</td>
<td>[19]</td>
</tr>
<tr>
<td>Lack of digital access</td>
<td>—</td>
<td>[23]</td>
<td>[18]</td>
</tr>
<tr>
<td>Insurance status</td>
<td>[12]</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Comorbidities such as vision and hearing loss, decreased dexterity and mobility, and declining cognitive function</td>
<td>—</td>
<td>—</td>
<td>[18,19]</td>
</tr>
<tr>
<td><strong>2. Technology</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Key features</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information and identity authentication and protection</td>
<td>—</td>
<td>[23,25]</td>
<td>—</td>
</tr>
<tr>
<td>Usability (eg, set-up, interface design, simple displays, text visibility, buttons, patient-friendly content, ease of navigation, personalized interface, and reminders to view)</td>
<td>[12,17,20]</td>
<td>[21,24,25]</td>
<td>[18]</td>
</tr>
<tr>
<td>Functionality (eg, communication with providers; access to reliable, timely and comprehensive personal medical information; content in minority languages; and inbuilt system alerts)</td>
<td>[17]</td>
<td>[23,24]</td>
<td>[18]</td>
</tr>
<tr>
<td>Accessibility (eg, adding mobile access and providing on-site kiosks)</td>
<td>[12]</td>
<td>[21,23]</td>
<td>—</td>
</tr>
<tr>
<td>Participatory and iterative design approaches</td>
<td>—</td>
<td>[23,24]</td>
<td>—</td>
</tr>
<tr>
<td>Iterative user evaluation (eg, patients and providers)</td>
<td>[12]</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Definition of minimum data set to plan care and continuously evaluate treatment</td>
<td>—</td>
<td>[25]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients’ security and privacy concerns (eg, control over access)</td>
<td>[17,20]</td>
<td>[21-24]</td>
<td>[18]</td>
</tr>
<tr>
<td>Providers’ concerns about sharing patient information</td>
<td>—</td>
<td>[21,25]</td>
<td>—</td>
</tr>
<tr>
<td>Usability (eg, interface design, technical glitches, log-on, navigation, accessibility of information for patients, and printing and using information)</td>
<td>[17]</td>
<td>[21,23,24]</td>
<td>[18,19]</td>
</tr>
<tr>
<td>Establishing a trade-off among security measures, user friendliness, and flexibility</td>
<td>—</td>
<td>[23]</td>
<td>—</td>
</tr>
</tbody>
</table>
### NASSS domain and subdomain and contextual factors (namely, facilitators and barriers)

<table>
<thead>
<tr>
<th>NASSS domain and subdomain and contextual factors (namely, facilitators and barriers)</th>
<th>Acute care hospitals</th>
<th>Mixed health care setting</th>
<th>Older adults (aged &gt;60 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functionality (eg, differing information needs of patients and providers; differing patient preferences over data content and input; diversity of health data types and formats and portal ability to handle the diversity of health data types and formats; data transparency—what data are released and to whom and how they are released; language used; and level of features [eg, reminders, dictionary, lifestyle advice, print capability, and user voice command])</td>
<td>[17]</td>
<td>[23-25]</td>
<td>[18]</td>
</tr>
<tr>
<td>Accessibility (eg, computer and internet access and secure and stable infrastructures)</td>
<td>—</td>
<td>[21-23]</td>
<td>[18]</td>
</tr>
</tbody>
</table>

#### Type of knowledge in play

**Facilitators**

- Data set is comprehensive, reliable, complete, understandable, and valid
- Audit trail for revisions to data

**Barriers**

- Concerns about patients’ ability to interpret test results and deal with sensitive information without professional support or interpretation
- Real-time (release of) information without real-time support
- Providers’ concerns about the reliability of patient-generated data (as basis for clinical decisions)

#### Knowledge to use

**Facilitators**

- Patient training and technical support (eg, videos, handbooks, hotline, and workshops)
- Training for providers

**Barriers**

- Quality of patient training
- Patients’ level of technology literacy (eg, perceived and actual skill and computer anxiety)

#### Technology supply model

**Facilitators**

- Portals that integrate into preexisting systems
- Interoperability (eg, information exchange and sharing)

**Barriers**

- Interoperability (eg, achieving appropriate data exchange among systems)

#### 3. Value proposition

##### Supply-side value

**Facilitators**

- Facilitates the processing of payments by insurance companies
- Trial period before purchase (ie, to test usability and estimate financial and organizational impact)
- Positive return on investment and impact on charges and costs

**Barriers**

- Trade-off among the type of architecture, responsiveness to local needs, and implementation time and cost (ie, decentralized and more expensive but more responsive and shorter implementation time)
- Establishing sound business case (eg, no standardized evaluation frameworks, no reimbursement structures for electronic services, lack of evidence of cost savings, and lack of financial sustainability)

##### Demand-side value

**Facilitators**


Older adults (aged >60 years) in mixed health care setting in acute care hospitals SATISFIES PATIENTS’ NEED FOR INFORMATION; FACILITATES KNOWLEDGE RETENTION, UNDERSTANDING, AND ENGAGEMENT IN CARE BY PATIENT; SENSE OF EMPOWERMENT AND CONTROL; FEELING OF BEING BETTER PREPARED; AND PERCEIVED USEFULNESS (EG, AIDS SELF-MANAGEMENT, UTILITY FEATURES, AND INFORMATION IN ONE PLACE) [17,20] [21,22,24,25] [18,19]

Provide communication route with professionals between clinic rounds (eg, patient-driven communication) [17] [21,24] [18]

Assists (verbal) interactions or appointments with professionals and patient-provider communication [17,20] [21,22,24,25] [18]

Access to information facilitates the development of trust in diagnosis, investigations, treatment, and professionals (eg, relationships) [20] [21] [19]

Helps inaccuracies in EHR to be identified (eg, detection of errors and patient safety) [17,20] [24] [18]

Contributes to enhanced discussions with patients and aids communication [17] [21,24,25] [20]

Prevents misunderstandings and builds trust (ie, careful and clear recording of information) [20] [21] [20]

Usefulness and time efficiency (ie, clear recording prevents the need to repeat information and aids interprofessional communication) [21,25] [21,25] [21]

Helps improve care (eg, planning and continuous evaluation of treatment, adherence, patient satisfaction and engagement, reduced patient anxiety, timely decision-making) [24,25] [21,25] [21]

**Barriers**

- Patients perceive extra responsibility for finding errors or poor outcomes [20] [18]
- Patients’ concern about threat to face-to-face communication with professionals [20] [18]
- Patients’ do not see value or usefulness (eg, lack awareness of features) [12] [21,23,24] [19]
- Patient views about “user fee for use” — [18]
- Professionals’ concern that messaging may adversely impact verbal communication [17] [19]
- Professionals do not perceive usefulness [21] [21]

4. Adopter system

**Changes in staff roles, practices, and identities**

**Facilitators**

- Accepting of collaborative versus expert-led care [20] — — —
- Professionals’ positive level of engagement, knowledge, and confidence in portal systems — [24] —

**Barriers**

- Less accepting of collaborative versus expert-led care and do not wish to cede autonomy to patients [20] [23] —
- Professionals need to support patients to interpret and emotionally deal with the information in portals [20] — —
- How is responsibility for the release of test results managed? (eg, who takes responsibility and editing before release) [20] — —
- Professionals’ level of engagement, knowledge, skills, and confidence in portals [2,21,23] —

**What is expected of patients?**

**Facilitators**

- Professionals support and encourage patients’ use of portals (eg, endorsement, reminders, and materials) — [22-24] —
- Patients’ willingness to enter basic information into portals or manage records — — [18,19]

**Barriers**

- Patient preferences regarding the entry of data into portals, increased knowledge, and managing records [20] [24] [18,19]
- Professionals or providers do not encourage patients’ use of portals — [23] —
<table>
<thead>
<tr>
<th>NASSS domain and subdomain and contextual factors (namely, facilitators and barriers)</th>
<th>Acute care hospitals</th>
<th>Mixed health care setting</th>
<th>Older adults (aged &gt;60 years)</th>
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<tbody>
<tr>
<td><strong>What is assumed about the network of lay care givers?</strong></td>
<td></td>
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</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td>None identified</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td>Patients lack help or support to access portals</td>
<td></td>
<td>18</td>
</tr>
<tr>
<td><strong>5. Organization</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Organization’s capacity to innovate</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td>Leadership involvement in portal design and development of policies for user training and the integration of patient portals into workflows</td>
<td>[24]</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Communication around technical, interpersonal, and workflow aspects of portals</td>
<td>[23]</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Organizational interpretation of government legislation related to portals</td>
<td>[24]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td>Constrained financial context (eg, small or rural hospitals)</td>
<td>[20]</td>
<td>[24]</td>
</tr>
<tr>
<td></td>
<td>Organizational interpretation of government legislation</td>
<td>[24]</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Lack of leadership support (fear and hesitancy in implementation)</td>
<td>[25]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Is the organization ready for technology-supported change?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td>Policies in place to support portals (eg, universal access policy, security protocols, adherence audits, data availability, and timing)</td>
<td>[12]</td>
<td>[23]</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td>Lack of support for new forms of communication between patients and professionals</td>
<td>[24]</td>
<td>—</td>
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<tr>
<td></td>
<td>Lack of policies on access rights and authorization process (including proxy access and access for minors)</td>
<td>[23]</td>
<td>—</td>
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<tr>
<td><strong>Ease of funding and adoption decision</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td>Internal and external exchange of information to improve the quality, safety, and effectiveness of care</td>
<td>[25]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td>Providers’ concerns about diverting resources to the less disadvantaged (ie, those who can read and ask questions)</td>
<td>[20]</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Integrating patient portal use across care transitions (ie, with other organizations) to improve care</td>
<td>[17]</td>
<td>[25]</td>
</tr>
<tr>
<td></td>
<td>Deciding on the balance between IT structure and implementation time and cost</td>
<td>[25]</td>
<td>—</td>
</tr>
<tr>
<td><strong>Changes needed in team interactions and routines</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Facilitators</strong></td>
<td>Integrating data release with workflow (ie, to facilitate professionals’ follow-up with patients)</td>
<td>—</td>
<td>[23]</td>
</tr>
<tr>
<td></td>
<td>Workload and work routines not adversely impacted or positively impacted (eg, time efficiencies)</td>
<td>—</td>
<td>[21]</td>
</tr>
<tr>
<td><strong>Barriers</strong></td>
<td>How to organize the release of results to patients without professionals’ help with interpretation and support (eg, real-time release or delayed released)</td>
<td>[20]</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Professionals’ concerns about the impact of increased level of patient questions, patient overuse of messaging, increase in documentation time, and portals on workflow</td>
<td>[17]</td>
<td>[21,23,24]</td>
</tr>
<tr>
<td><strong>Work involved in implementation and who will do it</strong></td>
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(page number not for citation purposes)
### NASSS domain and subdomain and contextual factors (namely, facilitators and barriers)

<table>
<thead>
<tr>
<th>NASSS domain and subdomain and contextual factors (namely, facilitators and barriers)</th>
<th>Acute care hospitals</th>
<th>Mixed health care setting</th>
<th>Older adults (aged &gt; 60 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facilitators</strong></td>
<td></td>
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<tr>
<td>Involvement of professionals in workflow engineering and the evaluation of the impact of portal use on workload and processes</td>
<td>[17]</td>
<td>[23]</td>
<td>—</td>
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<tr>
<td><strong>Barriers</strong></td>
<td></td>
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<tr>
<td>None identified</td>
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</table>

### 6. Wider context

**What is the political, economic, regulatory, professional, and sociocultural context of program rollout?**

#### Facilitators

- Aspects of culture (doctors from English-speaking countries), including the coverage of portals, PHRs\(^a\), and EHRs in medical and nursing school curricula
- Health professionals’ liability concerns
- Health systems with a transactional component
- Resource for policy makers, health care specialists, and stakeholders to improve care and the quality of treatment
- National and international information exchange (interoperability) and other standards (eg, Health Insurance Portability and Accountability Act, International Health Level 7, regional health information exchanges, and key public infrastructures)
- Appropriate reimbursement mechanisms

#### Barriers

- Reimbursement structures for electronic services
- Providers’ liability concerns (eg, breached privacy or patients’ harmful behaviors)
- Nonstandardized rules for developing and managing health information infrastructures
- Relationship between macrolevel and mesolevel (eg, organization) factors was not well explored
- Regulations (eg, Health Insurance Portability) do not cover portal developers and hosting organizations

### 7. Embedding and adaptation

**Scope for adapting and coevolving technology and service**

#### Facilitators

- None identified

#### Barriers

- Concern that medical record maintains integrity as a working document that facilitates the transfer of knowledge between health professionals

**Organization resilience to critical events**

#### Facilitators

- None identified

#### Barriers

- None identified

---

\(^a\)Not available.

\(^b\)EHR: electronic health record.

\(^c\)PHR: personal health record.
Domain 1: The Condition

What Is the Nature of the Condition or Illness?
The included reviews documented patient portals that are open to individuals with a variety of health conditions, including acute and chronic diseases and high-risk conditions. Reviews focusing on patient portals in acute care hospitals included adult patients with acute medical conditions [23], inpatients and outpatients classified as vulnerable (including those with cardiovascular diseases, those with HIV, those with ophthalmic conditions and those with chronic or unspecified conditions) [15], patients who have had cardiac surgery, patients who were in an intensive care unit, patients with cancer, parents of patients who were in a neonatal intensive care unit, and caregivers or patients who underwent bone marrow transplant. Reviews focusing on multiple care settings included patients with multiple sclerosis [28], patients in any medical domain [25], adult patients with chronic diseases, patients in family practice settings [24], and patients with unspecified conditions [26,27]. The reviews focused on older patients aged ≥60 years did not specify an illness or medical domain.

There was limited consideration of how clinical characteristics played a role in patient portal use. An examination of inpatient portals [27] highlighted patients’ desire to be able to view their daily schedule, view information on medications and test results, and learn about care and preparations for discharge. This review acknowledged how the nature of an individual’s condition (eg, severe illness or intense pain) could affect their ability or desire to interact with the functionality of a patient portal, as well as their capacity to be involved in decision-making about their care and to formulate and ask questions to health professionals [23,27].

A total of 3 (30%) reviews suggested that patients with greater disease severity [27] or with chronic disease [24,26] may engage more with a portal. Patients with chronic diseases (such as diabetes, hypertension, or depression) have the benefit of well-established case management programs [24]. Although this may facilitate the adoption of a portal, the authors noted that concomitant case management programs will also be a factor impacting disease outcomes (separate from any impact on patient outcomes from the portal), making the findings of disease-specific studies of patient portal implementation difficult to extrapolate across non-disease-specific populations [24].

What Are the Relevant Sociocultural Factors and Comorbidities?
The NASSS framework considers how complexity occurs when a condition or an illness is associated with sociocultural factors (eg, poverty or social exclusion) and comorbidities (eg, loss of function and multimorbidity of older age). The impact of these factors on patient portal adoption received more extensive coverage in the included reviews, along with concerns about the potential for the exacerbation of health inequalities owing to disparities in engagement, as outlined subsequently.

The included reviews suggested that portal adoption is associated with having a higher socioeconomic status, being female, being of White ethnicity, being younger, and being a younger senior citizen [21,26,27]. Low health literacy and numeracy in patient groups [21,22,27] as well as a lack of digital access [21,26] were identified as barriers to portal use. Vulnerable groups [15], those with lower socioeconomic status [15,23,27], and those with less favorable health insurance status [15] are less likely to be enrolled in or engage with patient portals. In addition, increasing age, male sex, and non-White ethnicity were identified as factors associated with low adoption [15,23,27].

Certain comorbidities, such as vision and hearing loss, decreased dexterity and mobility, and declining cognitive function, were identified as barriers to portal use [21,22]. These factors may be associated with the aging process; however, 1 (10%) review highlighted that the diversity of older adults and their needs relative to patient portals are not well understood [21].

Domain 2: The Technology

Material and Technical Features
The included reviews did not outline the technology in detail but identified several material and technical features that promote patient portal adoption and user satisfaction, including a well-designed interface [20,28], ease of setup and access [21], straightforward navigation [20] and information transfer [21], simple formats [20,23] and buttons [23], text visibility [28], user-friendly content [20], error messages [28], real-time [20] or disease-specific information [27], email reminders to view content [15], and a personalized interface [20]. Conversely, poor usability features, such as poor interface design [24,26,27], technical glitches [27], log-on [21] or navigation difficulties [21,22], and difficulties with printing and using information [22] were reported to have a negative impact on users’ experience, and satisfaction, with patient portals [20-22,24,26,27]. Moreover, 1 (10%) review suggested that if patients perceive the access to their personal health records as useful, they are more willing to overcome the technical barriers of engaging with the patient portal [22]. This is linked to domain 3 (the value proposition) in terms of the desirability or value of the portal technology for patients.

The reviews suggested that participatory and iterative design [26,27] and iterative user evaluation [15], including both patient and health professional users, at the planning and development stage of a patient portal are ways to overcome usability issues. Such inclusive and consultative design approaches also allow the functionality of patient portals to be addressed [20,26-28]. Reviews reported that patient engagement with portals can be facilitated by offering desired features, including communication with health professionals [20]; access to reliable, timely, and comprehensive personal medical information [27]; and content in minority languages [26]. The reviews also pointed to the benefits for health professionals from their involvement at the design stage, including the specification of a minimum data set for care planning and for the continuous evaluation of treatment [28], and from inbuilt system alerts (eg, if a patient does not open an email or to signal a medical emergency) [26].

Several reviews highlighted potential difficulties in defining the functionality of a patient portal system, including the differing information needs of patients and health professionals [20], differing patient preferences regarding data content and
data input [27], the diversity of health data formats [28], the language to be used (ie, designing content for lay and professional audiences) [26], the level of features (eg, reminders, dictionary of medical terms, lifestyle advice, and print and user voice command capability) [21], and data transparency (ie, deciding what data to release to patients and when and how to make them available) [26].

The information privacy and security aspects of patient portals were reported to be an area of concern. This could be patients’ concerns regarding their personal health information [20,21,23-27] or health professionals’ concerns about sharing patient information [24,28]. Measures such as robust identity authentication and information protection [26,28] were suggested as mechanisms to address such concerns, with the observation that there can be a trade-off between security measures and user friendliness [26].

Accessibility of the technology for patients [24], including computer [21] and internet [21,25] access, was highlighted as another barrier to the implementation of patient portals. This may be because of cost issues [21]. Suggested mechanisms to promote accessibility were making mobile as well as computer access available [15] and providing on-site kiosks [26]. Establishing secure and stable technical infrastructures on which portals can operate was reported to be a challenge for providers [26].

**Type of Data Generated or Knowledge in Play**

In terms of the data held in the patient portal, 1 (10%) review suggested that the data set needed to be comprehensive, reliable, complete, understandable, and valid [28], with another (10%) recommending the inclusion of an audit trail so that the revisions made to the data are visible [26]. Several reviews raised the issue of health professionals’ concerns about patients’ access to health information via portals, particularly sensitive information, with questions about how patients can deal with the information without professionals’ help with interpretation and support [20,21,23,24,26,27]. This concern particularly revolved around the issue of the real-time release of data or test results without real-time support [23] and is linked to domain 5 (the organization), whereby health professionals need to adapt to patient portal technology and incorporate it into their practice. Patient portals providing opportunities for patients to enter data about their condition raised additional questions about knowledge in play; 2 (20%) reviews reported that health professionals can have reservations about the reliability of patient-generated data in a portal and whether these data should form the basis of clinical decisions [23,26].

**Knowledge Needed to Use**

The reviews suggested that training and support can help portal use [15,26] and the use of specific features [15], helping to overcome the barrier of patients’ technology literacy [15,21,26], including perceived and actual computer and internet skills [21]. However, 1 (10%) review reported that it is possible for training to have unintended consequences (ie, decreased intention to use) [15]. The training of health professionals must also be addressed [26]. It was posited that various tools and aids can facilitate the understanding of portal concepts and navigation, health information, and health management tasks (eg, videos, user handbooks, hotlines, and workshops) [21].

**Technology Supply Model**

Although the included reviews did not address how the patient portal technology was procured, the lack of interoperability for achieving appropriate data exchange between systems was identified as a barrier to adoption [24,26]. Portals that can be integrated into preexisting systems or offer data sharing and exchange are identified as facilitators [20].

**Domain 3: The Value Proposition**

**What Is the Developer’s Business Case for the Technology (Supply-Side Value)?**

The reviews did not address the issue of the business case for patient portals from the developer’s perspective but did examine it from the health care system’s point of view, primarily with respect to the difficulties in establishing such a case [23,24]. Uncertainty around cost savings and financial sustainability, as well as reimbursement models for electronic services [26], contributes to complexity in this situation. The absence of standardized evaluation frameworks means that evidence of benefits (such as administrative efficiency or better-managed patients) is lacking. In addition, 1 (10%) review highlighted the challenge of deciding on a balance between technology architecture (ie, centralized or decentralized), its responsiveness to local needs, ease of implementation, and cost when compiling a business case; decentralized architectures are reportedly more compatible with local needs and can be implemented more quickly but have higher costs [28].

A recommendation for ensuring a sustainable business case was to have a trial period before committing to the purchase of a portal [26]. This allows the testing of usability and provides an opportunity to estimate the likely financial and organizational effects [26], such as the facilitation of the processing of payments [28]. It was suggested that determining a positive return on investment and the potential for lower hospital costs will support implementation [24].

**What Is the Desirability, Efficacy, Safety, and Cost-effectiveness (Demand-Side Value)?**

The reviews suggested that patient portals do satisfy patients’ need for information (eg, about hospital schedule, medication, test results, and discharge planning) [20-22,27,28], helping with knowledge retention [23] and interactions with professionals [20,21,23-25,27,28] and providing a communication channel between clinic rounds [20,21,24,27]. These features support patients’ understanding of their condition [22,24,25] and engagement in care or self-management [21,22,24,25,27], leading to a greater sense of empowerment and control [25,27] and feeling of being better prepared (ie, for appointments, emergencies, and discharge) [20,21]. In addition, the reviews indicated that access to information via the portal also facilitated the development of trust in health professionals [22-24], with patients feeling reassured by shared information [23].

Professionals valued patient portals as a mechanism for enhancing patient care [27] through timely decision-making.
[28], planning and continuous evaluation of treatment [28], and building trust [23,24] and as a mechanism that leads to improved patient engagement, adherence to treatment, and satisfaction with care [27,28]. Portals are also regarded as an aid to communication with patients [20,24,27,28] and as a tool to enhance interprofessional communication [24,28]. The clear recording of data in a portal was found to help efficiency by reducing the need to repeat information [24,28] and to contribute to patient safety by allowing inaccuracies and errors to be identified [20,23,27].

As indicated under domain 2 (the technology), where patients perceive portals as useful, they are prepared to overcome the technical barriers to portal use [22]. However, some reviews identified a lack of perceived usefulness from the patient perspective as a barrier to engagement with a portal [15,22,24,26,27], together with patient views about “fee for use” [22]. Some patients regarded portals as a threat to valued face-to-face communication with health professionals [21,23] or felt an additional (and unwelcome) burden of responsibility with respect to their care (eg, for finding errors or for poor outcomes) [23]. Some health professionals also did not see the usefulness or value of patient portals [24] or felt that they would adversely impact face-to-face communication with patients [20].

**Domain 4: The Adopter System**

**What Changes in Staff Roles, Practices, and Identities Are Implied?**

The reviews highlighted that the adoption of patient portals can raise questions regarding health professionals’ scope of practice and professional identity. There are implications in terms of health professionals’ confidence and ability to interact with the technology [24,26,27]; their need to incorporate the technology into their work practices [23]; and the potential for patient portals to alter the balance of the professional-patient relationship, shifting to more collaborative, rather than expert-led, working [23,26]. These elements are linked to considerations in domain 2 (the technology) regarding the involvement of health professionals at the portal design stage, as well as the provision of training and ongoing support for portal use, and to domain 5 (the organization) regarding the potential impact of patient portals on the workflow and workload of professionals and models of care and service delivery.

Moreover, 1 (10%) review suggested that when health professionals advocated collaborative working with patients and had confidence in using patient portals, this acted as a facilitator of implementation [23]. Conversely, where professionals were reluctant to cede professional autonomy and work more collaboratively with patients [23,26] or had concerns about their capacity and skills to engage with portal technology [24,26,27], this acted as a barrier to the implementation of patient portals. Examples of implications for practice included being able to support patients to interpret and emotionally deal with the information contained in the portal and deciding who takes responsibility for the release of information into the portal and whether the information needs to be edited before release [23].

**What Is Expected of the Patient (or Immediate Caregiver) and Is This Achievable by, and Acceptable to, Them?**

Professionals’ support and encouragement of patients’ use of portals were identified as mechanisms to facilitate the adoption of portals among patients [25-27]. Both (20%) the reviews that focused on older adults suggested that patients may be willing to enter basic data into the portal [21,22]. Patient engagement with portals is impacted by different preferences: some patients may not wish to have the responsibility of increased knowledge afforded by the portal [23] and do not wish to enter data [21,22,27] or be responsible for managing records [21].

**What Is Assumed About the Extended Network of Lay Caregivers?**

The included reviews did not directly address expectations of the involvement of the wider care network or lay caregivers in the adoption of patient portals, although it is acknowledged that older patients may lack help or support to access a portal [21]. This subject is linked to the information security and privacy concerns raised in domain 2 (the technology) and to the questions about policies on access (including proxy access) and security in domain 5 (the organization).

**Domain 5: The Organization**

**What Is the Organization’s Capacity to Innovate?**

The included reviews highlighted the importance of organizational leadership support in promoting portal adoption [27,28] through actions such as working with developers on portal design [27] and developing policies for user training (both patients and health professionals) and integrating portals into clinical workflows, as well as organizing communication around the technical, interpersonal, and workflow aspects of patient portals [28]. A lack of executive leadership support can lead to hesitancy with portal implementation [28].

One (10%) review pointed to the potential for variability in portal implementation (eg, content made available to patients) in situations where providers have the discretion to interpret government legislation [27]. This is connected with the issue of internal and external information exchange; domain 6 (the wider context); and the extent to which there are standardized, nationally mandated regulations for developing and maintaining health information technologies. This may also influence the value proposition for patients (domain 3).

A constrained financial context will impact the implementation of portal technology [23,27]. One of the included reviews highlighted resource constraints at small or rural hospitals [27] as a situation likely to make the adoption of patient portals more difficult.

**How Ready Is the Organization for Technology-Supported Change?**

The included reviews highlighted the range of preparatory work that organizations need to do to support portal implementation. Organizational policies such as universal access [15]; security protocols, including those related to proxy access and access for minors [26]; adherence audits [26]; and data availability and timing will facilitate portal development and implementation. One (10%) review pointed to the necessity for sufficient
organizational support for new forms of communication between patients and health professionals afforded by patient portals [27].

How Easy Will the Adoption and Funding Decision Be?
The challenges of making decisions on adoption and funding were highlighted by the included reviews. Organizations need to decide on the balance between costs, implementation time, and the flexibility of the portal architecture [28], including the ability to integrate portal use across care transitions (ie, interoperability with other organizations) [20,28]. There may be concerns that portals divert scarce resources to those who are less disadvantaged (ie, those who can read and have the confidence to ask questions) [23]. However, enhanced communication through internal and external exchange of information may offer positive advantages for the quality, safety, and effectiveness of patient care [28].

What Changes Will Be Needed in Team Interactions and Routines?
Concerns among health professionals regarding the potential impact of patient portals on workload and workflow were identified in the reviews [20,24,26,27], including the possibility of an increased level of patient questions [20], the potential for patient overuse of portal messaging functions [20], the question of how to respond to patient inquiries in a timely manner [26], and an increase in documentation time [24]. A related concern was how to manage and organize the release of results to patients without the presence of a health professional to offer help with interpretation and support [23].

Some solutions addressing workflow concerns were presented, including integrating data release to patients with workflow patterns to facilitate health professional follow-up with patients when the results are made available [26] and providing evidence for a positive impact on workflow and workload (eg, time efficiencies) [24].

These issues are linked to the involvement of health professionals at the technology design stage (domain 2), where concerns about the potential impact on workflows can be raised, and to the points raised earlier about the development of policies around integration by organizational leadership and proactive communication around the integration of portals into workflows.

Domain 6: The Wider Context

What Is the Political, Economic, Regulatory, Professional, and Sociocultural Context for Program Rollout?
The included reviews suggest the development of national and international information exchange (ie, interoperability) and other standards (eg, security) as a facilitator of portal implementation [26,28].

One (10%) review identified health professionals’ liability concerns as a factor that will promote patient access to records (eg, in countries such as Norway and the United States) [23]. For countries with health systems that have a transactional component (eg, the United States), it is posited that portals can act as a mechanism for helping patients understand their health care costs and that this will encourage the provision of the technology [23]. Other cultural components identified as important for adoption included the coverage of portals in medical and nursing school curricula [26] and the perceived benefit of portal data sets as a resource for policy makers, health care specialists, and stakeholders to evaluate and improve care [28].

Barriers to portal implementation identified in the reviews included nonstandardized rules for developing and managing health information infrastructures (ie, for interoperability) and regulations for data protection and management (eg, Health Insurance Portability and Accountability Act in the United States) that do not cover portal developers or hosting organizations, creating uncertainty about appropriate data governance [26]. In addition, it was pointed out that providers may have liability concerns about privacy breaches or patients’ harmful behaviors [26].

One (10%) review pointed to inadequate or contradictory reimbursement structures for electronic services as a wider contextual barrier to the implementation of patient portals [26], inhibiting the development of a sound business model (link to domain 3). This review cited the Meaningful Use program in the United States as an example of a national initiative for patient portal adoption that was hampered by modest incentives and high thresholds, which impeded the development of an adequate business case [26].

Domain 7: Embedding and Sustaining

How Much Scope Is There for Adapting and Coevolving the Technology and Services Over Time?
In the included reviews, there was little consideration of the long-term adaptability and sustainability of the patient portals. The focus of attention was on development and short-term implementation issues.

Two long-term considerations were mentioned in the literature. The first was a general concern that the medical record maintains its integrity as a working document that facilitates the transfer of knowledge among many health professionals [23]. The second was related to the fact that most portals are implemented within a single organization or organized care delivery system, which limits their relevance to other organizational contexts [26]. Portal implementation will be more challenging across organizational contexts or in fragmented care delivery contexts, which are situations that are likely to feature in older people’s care.

How Resilient Is the Organization to Handling Critical Events and Adapting to Unforeseen Eventualities?
There was no coverage of organizational resilience to critical or unforeseen events and ability to adapt to them.

Coverage and Interactions Between NASSS Domains

Table 2 shows that the contextual factors influencing implementation identified in the included reviews tended to cluster in specific domains: (1) the condition, (2) the technology, and (3) the value proposition. Certain aspects within these domains received more coverage than others, such as sociocultural factors and comorbidities, the usability and functionality aspects of the technology, and the demand-side value. The included reviews that used a theoretical framework
There are links among the different domains. For example, the severity of an individual’s illness can affect their ability to interact with portal technology, raising questions about expectations of the involvement of lay caregivers (domain 4: the adopter system), organizational policies on proxy access (domain 5: the organization), privacy and security features (domain 2: the technology), and information governance (domain 6: the wider context). Similarly, organizational leadership and support (domain 5: the organization) for the development and implementation of portals can ensure inclusive and iterative portal design (domain 1: the technology), addressing not only usability and functionality issues but also the perceived value (domain 3: the value proposition) of the technology, as well as concerns about the impact of portals on health professional roles and identities (domain 4: the adopter system) and workload and workflow (domain 5: the organization).

There are gaps in the literature pertinent to the consideration of the provision of patient portals among older people in acute care hospitals, including the lack of consideration of the diversity of older adults and their needs, the question of interoperability between systems (likely to be important where care involves multiple services), the involvement of lay caregivers and looking beyond short-term implementation to ways in which portal use can be sustained.

**Discussion**

**Summary of Key Findings**

This scoping review provides an overview of the contextual factors that impact the implementation of patient portals through an exploration of the emerging literature on patient portal use and engagement in acute care hospitals and among older people. Patients with chronic disease or greater disease severity were found to engage more with portals; however, comorbidities associated with the aging process were identified as barriers to portal use (domain 1: the condition). Perceived benefits from the supply side supported the adoption of portals, such as the potential for lower hospital costs, as did benefits from the demand side, such as engagement in care or self-management (domain 3: value proposition). Training for patients and staff should address technology literacy, the use of portal features, capacity-related concerns (integration of portals into workflows), and perceived value among health care professionals (domain 2: the technology). Older patients may lack help or support to access a portal; however, expectations of the involvement of lay caregivers in the adoption of patient portals were not reported (domain 4: the adopter system). Organizational leadership facilitates portal adoption, such as working with developers on portal design, developing policies for user training, and integrating portals into clinical workflows (domain 5: the organization). The development of national and international information exchange (ie, interoperability) and other standards (eg, security) was as a facilitator of portal implementation within the wider context (domain 6: the wider context). The reviews did not report on the long-term adaptability or sustainability of patient portals or organizational resilience. There were concerns that most portals are implemented within a single organization and that implementation across organizational contexts or in fragmented care delivery contexts would be challenging. This is important for the care of older people (domain 7: embedding and sustaining).

**Older People and Inequalities**

The diversity of older adults and their patient portal needs are not well understood. Older patients are more likely to experience chronic disease or greater severity of disease, and patients with chronic illness and greater severity of disease were found to engage more with portals owing to the perceived benefits of self-management, empowerment, and enhanced patient care. However, comorbidities related to age, such as vision and hearing loss, decreased dexterity and mobility, and declining cognitive function impede portal use. Variability in portal use and engagement among older people will, in part, be linked to the reasons for variability in internet use. Low income is the largest impediment to internet use among older people, followed by being aged >75 years, living alone, mobility, and memory or concentration problems [29]. This scoping review found that lower socioeconomic status, increasing age, male sex, and non-White ethnicity were factors associated with low adoption. People of lower socioeconomic status, older people, and people with mobility and memory or concentration problems are regular users of acute care services, making it an ideal setting to address these inequalities in patient portal access and engagement. Training programs and other engagement activities must directly target these inequalities to prevent any unintended exacerbation of the gray digital divide caused by the introduction or widespread use of a patient portal.

**Adopter System**

An important gap in the literature identified by this review was the lack of consideration of the involvement of the wider care network or lay caregivers in the adoption of patient portals. Many impediments to internet use among older people are linked to the increased likelihood of receiving care, for example, older age, mobility, and memory or concentration problems [29]. Older people are found to value proxy access to patient portals [30], with motivators including help to manage care, in the event of an emergency and lack of technology experience [31]. However, older patients express concerns when portals contain access to stigmatized conditions and financial commitments [32]. A review of 20 US health systems found that half of them had proxy access functionality, although only a few allowed the patient to specify role-based privileges [33]. The provision of separate proxy access should be accompanied by the provision of more control for patients over the information they wish to share [34]. This review found that organizational policies such as universal access; security protocols, including proxy access; adherence audits; and data availability and timing will facilitate portal development and implementation. To further aid the organizational readiness for technology-supported change, wider contextual factors must be considered at the planning stage in the form of policy shifts and patient developer specifications regarding the facility for internal and external information.
believe these similarities reinforce our robust approach to publication of the review conducted by Antonio et al [14]. We was designed and our searches were conducted before the there were similarities with the umbrella review conducted by settings and patients. In broadening the scope of the review, learning and potential generalizability of the findings across hospitals (3/10, 30%) and older people (2/10, 20%) was low, The number of reviews that focused exclusively on acute care programs, but more recently, the framework has been used to largely been used to predict and evaluate implementation to explore multilevel contextual factors impacting the NASSS framework provides a semantic structure by which track overlap in the reference lists of all the included reviews. indicating that study overlap was minimal, although we did not that 19 (9.2%) of these 206 studies appeared in >1 review, review included 156 primary studies and 50 reviews. We found systematic review and hence findings are overemphasized. This This scoping review used a comprehensive set of search terms strengths and implemented more quickly but were associated with higher costs [28]. Furthermore, there is no information on the level of support provided by the technology suppliers for the use of their products. This is anticipated to be a major organizational level barrier to implementation, which needs to be promptly addressed to facilitate the scale-up of portal use in acute care hospitals across the United Kingdom. Ports that can integrate into preexisting systems or offer data sharing and exchange were identified as facilitators [20]. Interoperability of health and care systems and other community services, such as the police and social services, is placed high on the NHS agenda [5], but although organizations may desire data sharing among themselves, the loss of control over shared data may serve as a barrier to portal adoption and highlights the complexity of this approach. Strengths and Limitations This scoping review used a comprehensive set of search terms to identify literature from electronic databases and followed robust procedures for citation and full-text screening in duplicate. Study overlap is a recognized limitation of reviews of reviews, where the primary studies may be reported in >1 systematic review and hence findings are overemphasized. This review included 156 primary studies and 50 reviews. We found that 19 (9.2%) of these 206 studies appeared in >1 review, indicating that study overlap was minimal, although we did not track overlap in the reference lists of all the included reviews. The NASSS framework provides a semantic structure by which to explore multilevel contextual factors impacting the implementation of digital health interventions. NASSS has largely been used to predict and evaluate implementation programs, but more recently, the framework has been used to synthesize review findings [35,36]. The number of reviews that focused exclusively on acute care hospitals (3/10, 30%) and older people (2/10, 20%) was low, which led to a broader scope of the extensive literature, primarily conducted in family practice and other patient groups, to capture learning and potential generalizability of the findings across settings and patients. In broadening the scope of the review, there were similarities with the umbrella review conducted by Antonio et al [14], who used a similar search strategy and a knowledge translation tool to present their findings. Our review was designed and our searches were conducted before the publication of the review conducted by Antonio et al [14]. We believe these similarities reinforce our robust approach to reviewing and synthesizing the literature, particularly as our design aimed to scope and map the literature rather than to systematically review it. The key differences between the reviews include our focus on older people and acute care hospitals; our review design aimed to scope rather than systematically review and appraise the literature; and our application of the NASSS framework. The NASSS has been referenced in >70 JMIR published studies since its publication in 2017, enabling easy comparison with the wider literature. Papers were selected in accordance with our definition of a patient portal, and we were guided by the authors’ description of a patient portal. Multimedia Appendix 1 shows the definition of patient portals in each of the included studies. The use of the NASSS framework is concerned with the complexity of the use of portals; therefore, all data were considered according to the framework to produce a “big picture” aggregation of what is known about the implementation of patient portals. The included reviews were limited to those published in English; however, we did not exclude reviews that included non-English studies. Recommendations for Research There is substantial literature on the contextual factors impacting patient portal use, with approximately 200 studies identified by the included reviews. However, there are few studies that evaluated interventions to address disparities in the use of patient portals [15]. As highlighted in a systematic review on the implementation of complex interventions in family practice [37], implementation studies exploring contextual factors tend to focus on surveys and qualitative studies, which are valuable in providing individual stakeholder perspectives but need triangulation with other methods. Observation and document analysis should accompany interviews to capture a more complete picture of the contextual factors at play, in particular, the wider context. As with any study exploring or evaluating the determinants of implementing a complex intervention, the features and functionality of the portal should be described in detail using established guidance [38] to enable reflection on the transferability of the findings to other settings. Finally, where interviews are used to explore the determinants of implementation among patients and staff, portal use data could be used to prompt further examination of use and sustained use. Recommendations for Practice This review provides implications for portal adoption and implementation that can inform current practice. This review found that cost, interoperability, trialability, and adaptability were all facilitators of portal adoption. Among hospitals in England deciding which portal product to adopt, GDE trusts play an important role in sharing detailed journeys through a digital technology via GDE blueprints, which are intended to promote scale-up, spread, and sustainabililty. To maximize the impact of GDE blueprints, they must be reported in an honest and transparent manner, with details on the challenges as well as the benefits of portals’ adoption, engagement, and sustained use. Descriptions of portal implementation must clearly delineate implementation strategies, such as detailed information on training for staff and patients (ie, content, frequency, and format) and communication strategies for the technical, interpersonal, and workflow aspects of patient portals. NHS Digital has created
a Personal Health Records adoption toolkit, which offers generic support to organizations looking to implement a patient portal [39]. Furthermore, GDE trusts act as buddy sites to support other trusts, known as “Fast Followers,” for example, by sharing software, IT teams, standard processes, and could possibly assist with the selection and implementation of a patient portal; this approach is a powerful knowledge mobilization strategy enabling successful models to be scaled-up across the NHS [4].

Conclusions
This scoping review found that contextual factors influencing patient portal implementation tended to cluster in specific domains: (1) the condition, (2) the technology, and (3) the value proposition. Certain aspects within these domains received more coverage than others, such as sociocultural factors and comorbidities, the usability and functionality aspects of the technology, and the demand-side value. There are gaps in the literature pertinent to the consideration of the provision of patient portals for older people in acute care hospitals, including the lack of consideration of the diversity of older adults and their needs, the question of interoperability between systems (likely to be important where care involves multiple services), the involvement of lay caregivers, and looking beyond short-term implementation to ways in which portal use can be sustained. There is substantial literature on the contextual factors impacting patient portal use. Future research should focus on evaluating strategies that address disparities in use and promote engagement with patient portals among older people in acute care settings.

Acknowledgments
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Conflicts of Interest
HJ is a member of the digital management team at a Global Digital Exemplar National Health Service trust and has management responsibility for the implementation of a patient portal (Oracle Cerner HealtheLife). She has presented at Cerner conferences and received travel and hospitality reimbursement from Cerner.

Multimedia Appendix 1
Characteristics of included reviews.

References


**Abbreviations**

GDE: Global Digital Exemplar  
NASSS: Non-adoption, Abandonment, Scale-up, Spread, and Sustainability  
NHS: National Health Service  
PRISMA-ScR: Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews

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How Older Persons and Health Care Professionals Co-designed a Medication Plan Prototype Remotely to Promote Patient Safety: Case Study

Malin Holmqvist1,2, RPh; Axel Ros3,4, MD, PhD; Bertil Lindenfalk4, MSc; Johan Thor4, MPH, MD, PhD; Linda Johansson5, RN, PhD

1Department of Public Health and Healthcare, Region Jönköping County, Jönköping, Sweden
2School of Health and Welfare, Jönköping University, Jönköping, Sweden
3Futurum, Region Jönköping County, Jönköping, Sweden
4Jönköping Academy for Improvement of Health and Welfare, School of Health and Welfare, Jönköping University, Jönköping, Sweden
5Institute of Gerontology, School of Health and Welfare, Jönköping University, Jönköping, Sweden

Corresponding Author:
Malin Holmqvist, RPh
Department of Public Health and Healthcare, Region Jönköping County
Box 1024
Jönköping, 55111
Sweden
Phone: 46 706702569
Email: malin.m.holmqvist@rjl.se

Abstract

Background: Harm from medications is a major patient safety challenge. Most adverse drug events arise when a medication is prescribed or reevaluated. Therefore, interventions in this area may improve patient safety. A medication plan, that is, a plan for continued treatment with medications, may support patient safety. Participation of patients in the design of health care products or services may improve patient safety. Co-design, as in the Double Diamond framework from the Design Council, England, can emphasize patient involvement. As the COVID-19 pandemic brought restrictions to face-to-face co-design approaches, interest in remote approaches increased. However, it is uncertain how best to perform remote co-design. Therefore, we explored a remote approach, which brought together older persons and health care professionals to co-design a medication plan prototype in the electronic health record, aiming to support patient safety.

Objective: This study aimed to describe how remote co-design was applied to create a medication plan prototype and to explore participants’ experiences with this approach.

Methods: Within a case study design, we explored the experiences of a remote co-design initiative with 14 participants in a regional health care system in southern Sweden. Using descriptive statistics, quantitative data from questionnaires and web-based workshop timestamps were analyzed. A thematic analysis of the qualitative data gathered from workshops, interviews, and free-text responses to the survey questions was performed. Qualitative and quantitative data were compared side by side in the discussion.

Results: The analysis of the questionnaires revealed that the participants rated the experiences of the co-design initiative very high. In addition, the balance between how much involved persons expressed their wishes and were listened to was considered very good. Marked timestamps from audio recordings showed that the workshops proceeded according to the plan. The thematic analysis yielded the following main themes: Everyone’s perspective matters, Learning by sharing, and Mastering a digital space. The themes encompassed what helped to establish a permissive environment that allowed the participants to be involved and share viewpoints. There was a dynamic process of learning and understanding, realizing that despite different backgrounds, there was consensus about the requirements for a medication plan. The remote co-design process seemed appealing, by balancing opportunities and challenges and building an inviting, creative, and tolerant environment.

Conclusions: Participants experienced that the remote co-design initiative was inclusive of their perspectives and facilitated learning by sharing experiences. The Double Diamond framework was applicable in a digital context and supported the co-design process of the medication plan prototype. Remote co-design is still novel, but with attentiveness to power relations between all
involved, this approach may increase opportunities for older persons and health care professionals to collaboratively design products or services that can improve patient safety.

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**KEYWORDS**

c-Design; remote; older people; medications; medication plan; patient safety; patient experience; participatory; engagement

**Introduction**

Harm caused by medications, often known as adverse drug events (ADEs) [1], is recognized by the World Health Organization as 1 of the 3 greatest patient safety challenges [2]. The older population, defined here as those aged ≥75 years, tends to be more prone to ADEs due to a higher prevalence of illness and multiple medications [3]. Errors related to ADEs tend to arise when medications are prescribed or reevaluated [4]. Therefore, interventions in these areas may improve safety. Safe clinical management of medications in older persons may be supported by a plan for continued treatment [5]. Such a plan, a medication plan, articulating what to observe when using medications (expected and adverse effects), when to act, and who should take the initiative when needed, may facilitate resilient performance, that is where a system adjusts to maintain a desired level of performance [6].

Having patients participate in the design of health care processes can improve patient safety [7]. In Sweden, as in many other countries, regulations and national policies strengthen and clarify patients’ position and promote their integrity and participation in health care [8]. Furthermore, persons invited to participate in initiatives aimed at improving patient safety are generally willing to do so [9]. There is still a lack of methods for patients to be involved in efforts to improve patient safety [10]. O’Hara and Lawton [11] outline opportunities to improve patient involvement in design and improvement initiatives for patient safety, highlighting the need to explore ways to engage susceptible patients, such as older persons, on their terms, as they tend to be at the highest risk for adverse events. If they are not involved, it may limit the generalizability of improvement efforts, as they may not reflect the reality of older people. So far, the dominant approaches to involving patients in patient safety initiatives include making them more aware of risks and comfortable with giving feedback about safety concerns rather than having them participate in improvement initiatives [12].

Co-design is an approach that emphasizes patient involvement in the improvement of health care services [13]. It enables participants to share experiences, where each participant’s experience is considered their expertise [14]. A co-design process is powerful, yet challenging, as both patients and health care professionals need to negotiate their roles and balance power between them [15]. Co-design is now an established approach in health care [16]. Even so, initiatives involving older persons are scarce, but some initiatives have addressed the development of different electronic health care tools [17,18] or improvement of specific health care services [19]. There are different frameworks for co-design in health care [16,20], including the Double Diamond from the Design Council, England [21]. The Double Diamond has 4 phases: Discover, Define, Develop, and Deliver (Figure 1). The Discover phase explores the problem space from a service user perspective, whereas the Define phase synthesizes insights to understand how service users are affected by the problem. The Develop phase encourages the exploration of potential solutions to the problem, which in the subsequent Deliver phase are tested and improved before they are incorporated into daily practice.

Although co-design approaches are increasingly common in health care, they are criticized for a lack of evaluation of their effectiveness and cost-effectiveness [22] and are seen as challenging to implement in a busy health care environment. Therefore, the application of any co-design framework must be adapted to the contextual needs of the health care system. The COVID-19 pandemic brought restrictions to co-design approaches, which are usually performed face-to-face with users. Remote co-design may have both limitations and strengths, but it seems possible to perform with similar outcomes and quality as face-to-face co-design efforts [23,24]. Remote co-design initiatives including older persons and health care professionals to support patient safety seem rare, and their potential and limitations are not fully understood. Therefore, we report the experiences of such an initiative concerning patient safety. This study aimed to describe how remote co-design was applied to create a medication plan prototype and to explore participants’ experiences with this approach.
Methods

Study Design

We report on the co-design initiative using a case study design [25]. Case study methods are useful when exploring efforts to improve patient safety in complex systems such as health care [26]. Qualitative and quantitative data were first analyzed separately and then included in a side-by-side comparison in the discussion.

Participants and Setting

The co-design initiative was part of a large national initiative introducing Patient Contracts, aiming to strengthen patients’ role in health care [27]. A Patient Contract is an agreement, documented in the electronic health record, intended to strengthen the relationship between a patient and caregivers by promoting care coordination, accessibility, and predictability. To achieve a variety of perspectives and experiences [28], we sought a balanced group composition with an equal number of older persons (aged >75 years), next of kin, general practitioners, and nurses working in municipality-based home health care. Participants were recruited through existing contacts within the initiative Patient Contract in 1 regional public health care system in southern Sweden, serving a population of 350,000 residents [27]. Inclusion required availability to participate in all 3 parts of the initiative, adequate communication capability in Swedish, and access to and comfort in using the internet. There were no explicit exclusion criteria for this study. Gender, age, and number of medications were noted for older persons; for health care professionals, gender and years in the profession were noted.

The initiative included 14 participants (Table 1): 3 general practitioners who had worked for 5-39 years as physicians, 6 nurses who had worked for 4-35 years as registered nurses, and 5 older persons aged 72-82 years and using 3-8 medications daily. One of the older persons also reported having the experience of being next of kin to a person taking medications.
Table 1. Number of participants and data collected at each step of the study (N=14).

<table>
<thead>
<tr>
<th>Session</th>
<th>Participants, n (%)</th>
<th>Data collected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Older persons, n (%)</td>
<td>General practitioners, n (%)</td>
</tr>
<tr>
<td>Workshop 1 (n=14)</td>
<td>5 (36)</td>
<td>3 (21)</td>
</tr>
<tr>
<td>Workshop 2 (n=14)</td>
<td>5 (36)</td>
<td>3 (21)</td>
</tr>
<tr>
<td>Survey (n=13)</td>
<td>5 (38)</td>
<td>3 (23)</td>
</tr>
<tr>
<td>Interviews (n=7)</td>
<td>4 (57)</td>
<td>1 (14)</td>
</tr>
</tbody>
</table>

The Co-design Initiative

The co-design initiative (Figure 2) aimed to create a prototype, that is, a model of a proposed solution, for a medication plan incorporated in the electronic health record to support older persons and health care professionals jointly in using and monitoring medications. This initiative focused on the Define and Develop phases in the Double Diamond framework and was informed by the guide “Design methods for developing services” by the Design Council [29]. The first phase of the Double Diamond, Discover, has been performed before [30,31], and the last phase, Deliver, will be performed later. This co-design initiative was performed over a 2-month period and included 3 sessions: 2 workshops via the web-supported Zoom (Zoom Video Communications) videoconferencing software and 1 survey session (Multimedia Appendix 1).

Figure 2. The structure of the co-design initiative.

Two facilitators, the first author and one quality improvement adviser, guided the participants through the co-design initiative. Two additional persons provided technical support, collected notes on the Padlet Web platform (a digital notice board), recorded audio, and encouraged collaboration during the workshops.

The workshops lasted for 2 hours each and were guided by a minute-by-minute timetable. The timetable was set up by the first and third author (with experience in co-design), together with the quality improvement adviser, detailing all planned activities (Multimedia Appendix 2). The setup for the workshops was pilot-tested to identify and resolve challenges to the digital collaboration. One week before each session, all participants received general information about the session along with specific input: before workshop 1, insights generated in the Discover phase and before workshop 2, the design brief and medication plan drafts and along with the survey, the medication plan prototype. To ensure that everyone received the information, it was sent out by both postal mail and email. Between the 3 sessions, facilitators presented data from the co-design initiative to eHealth designers in the regional public health care system where the initiative was performed, which informed their prototype design.

In the Define phase, including the first workshop, participants were invited to analyze the findings from the Discover phase, when insights about the evaluation of medications were gathered from older persons, nurses, and general practitioners [30,31] along with information from research studies and regulations related to the initiative. Furthermore, they were asked to synthesize their analysis into a number of opportunities for a medication plan. Brainstorming was used to gather ideas and build a shared understanding of the orientation of the group. After the session, the first author formed a design brief, that is, a core reference point based on gathered data produced during
the session, and presented it to the eHealth designers, who used it to assist in preparing medication plan drafts, that is, preliminary prototypes.

In the Develop phase, including the second workshop and the concluding survey, participants were invited to develop the drafts further into 1 prototype by designing components in detail and iteratively refining the draft. Experience Prototyping, a way to test and refine a solution in feedback loops with potential users, with made-up fictitious patient cases, was used to enable participants to gain first-hand understanding of the drafts and gather feedback from them. After the second workshop, the first author gathered data produced during the session and presented it to the eHealth designers, further informing the design of the medication plan prototype. This prototype was sent out to all participants together with a survey, open for 2 weeks, to collect final feedback on the prototype.

Data Collection

This case study of the co-design initiative draws on quantitative and qualitative data (Table 1).

Audio recordings of the workshops were transcribed verbatim and marked with timestamps. Zoom Polls (ie, questions) about the participants’ experience of the workshop, with fixed response options on a 4-grade Likert scale, ended each workshop. A survey, created in the web-based survey tool esMaker NX3, was sent out to all participants to collect feedback and reflections related to the co-design activities, participation in the activities, and practicalities of participating. It consisted of 7 questions with answers on a 10-grade Likert scale and with a possibility to add free-text comments, 1 yes or no question, and 7 additional free-text questions. The participants had 2 weeks to respond and received 2 reminders, after 1 week and on the last day for completion. All participants were invited to participate in an individual semistructured interview on Zoom. The interview guide (Multimedia Appendix 3), developed by the research team based on the findings from the survey, included questions about the prototype and the co-design process. The interviews were audio recorded, transcribed verbatim, and lasted between 21 and 46 minutes (30:37 SD 9:13).

Data Analysis

Quantitative data from the Zoom Polls and survey were analyzed using descriptive statistics. Marked timestamps in the workshop audio recordings were compared with the original timetable.

Qualitative data from the free-text responses in the survey and the transcribed audio recordings from workshops and interviews were analyzed together through thematic analysis, as outlined by Braun and Clark [32,33]. An inductive approach was applied to look for patterns, that is, to identify themes addressing the underlying meanings of data. To support the analysis, transcriptions and free-text responses were gathered using the NVivo software (QSR International). Initially, the material was read and reread to strengthen familiarity with data. The first author generated the initial codes and gathered them into potential themes. Then, the first and last authors reviewed the initial codes and themes and presented them to the entire research group to define the final themes. The entire research team contributed to writing and rewriting the descriptions of the themes and to generating the report.

Ethics Approval

This study was approved by the Swedish Ethical Review Authority (dnr 2020-04781) and adhered to the Declaration of Helsinki [34]. All participants received written information regarding the aim and arrangement of the study and provided written consent before the first session. Data were deidentified to maintain confidentiality and were presented so that no individual could be identified. Data from the study were kept secure at Region Jönköping County.

Results

Quantitative Data Regarding Experiences of the Remote Co-design Initiative

Using Zoom Polls, participants (13/14, 93%) assessed the first workshop as good (9/13, 69%) or very good (4/13, 31%). The participants’ (12/14, 86%) experience after the second workshop was fairly good (2/12, 17%), good (5/12, 42%), or very good (5/12, 42%). For the yes or no question in the survey, they (11/12, 92%) responded that the initiative corresponded to the aim, that is, to develop a medication plan prototype together; 1 respondent did not know. On the following survey questions, participants (13/14, 93%) responded with answers on a 10-grade Likert scale (Table 2). They reported being able to speak to the extent they wanted (median response 9) and that the views they expressed were considered when developing the prototype (median response 9). On a scale of 1 being very bad and 10 being excellent (Table 3), participants’ (12/14, 86%) experience after the second workshop was fairly good (2/13, 15%), good (5/12, 42%), or very good (5/12, 42%). The participants’ (12/13, 92%) experience at the end of the first workshop as good (9/13, 69%) or very good (4/13, 31%). On a scale of 1 being very critical and 10 being excellent, participants’ overall experiences of participating in the co-design initiative, the balance between how much all involved expressed their wishes, and the information provided to facilitate participation were close to excellent (median response 9). On the same scale, the participants indicated that the practical parts of the workshops facilitated participation and that the balance between how much all involved were listened to was almost excellent (median response 8).

Marked timestamps from the workshop audio recordings showed that both workshops ended according to the schedule (Multimedia Appendix 2). Presentations of activities took in general less time than planned in both workshops. The background introduction in the first workshop took longer than planned. In the second workshop, the introduction to and test of the digital notice board took longer than planned. The time for individual reflections was shorter than planned, whereas prioritizing the requirements for the medication plan took more time than planned.

Remote Co-design Initiative
Table 2. Answers from the survey (Q=question number) on a 10-grade Likert scale (13/14, 93%)a.

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Do not</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q4. In the workshops I was allowed to speak to the extent that I wanted</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>0</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Q2. The views I expressed in the workshops were taken into account in developing the medication plan prototype</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

a=do not agree to 10=totally agree.

Table 3. Answers from the survey (Q=question number) on a 10-grade Likert scale (13/14, 93%)a.

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Do not</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. What is your overall experience of participating in the work of creating a medication plan prototype?</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Q6. How did you experience the balance between how much older persons, general practitioners and nurses expressed their wishes?</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Q7. How did you experience the balance between how much the views of older persons, general practitioners and nurses were listened to?</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Q8. How did you perceive that information provided before, during, and after the workshops facilitated your participation?</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Q9. How did you experience that the practical parts of the workshops (that is, use of the digital platform, the facilitators’ actions) facilitated your participation?</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

a=From 1=very bad to 10=excellent.

Qualitative Data Regarding Experiences of the Digital Co-design Initiative

Thematic analysis included interviews, workshops, and free-text responses to questions in the survey. A total of 3 main themes and 11 associated subthemes were identified, which described the experiences of the approach (Textbox 1). The main themes Everyone’s perspective matters, Learning by sharing, and Mastering a digital space encompass conditions of importance for establishing a permissive, dynamic, and appealing remote co-design process, as described in the following text.

Everyone’s perspective matters reflects the experiences of a permissive environment during the co-design process, which allowed the participants, especially older persons, to be involved and share viewpoints that were taken into account when developing the prototype.

On the basis of their different perspectives and backgrounds, the participants experienced that they were contributing from multiple viewpoints to the design of the prototype. The purpose, that is, to improve medication safety, seemed to be important when participants decided to participate, as it was something worthwhile for them to affect. Contributing with different viewpoints in the workshops was considered to add broader input to the prototype, something not possible to extract from the existing literature. With different perspectives, both as individuals and as representatives of a group of people, the participants complemented each other, which means that the prototype was created collaboratively:

I think that…what I heard from the nurses in other municipalities as well, it is pretty much the same thoughts as we shared. But I think we complemented each other quite well. [Interview—nurse]

The atmosphere in the workshops was inviting to dialog. Together, facilitators and participants created opportunities for the exchange of perspectives by inviting all participants, regardless of who, to provide input and by allowing everyone to speak:

Yes, but I think we had the opportunity to speak, especially at the group meetings. [Survey—older person]

Participants’ viewpoints were taken into consideration in the development of the prototype, meaning that everyone counted. Even so, concerns were raised that some people, regardless of their roles, occupied more space than others. At the same time, different ways to inform the development of the prototype during the process, that is, by dialog, Zoom Polls, and note boards were appreciated as they gave participants opportunities to provide input into the process, including ideas that popped up between sessions.
Textbox 1. Themes and subthemes.

<table>
<thead>
<tr>
<th>Themes and subthemes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Everyone’s perspective matters</td>
</tr>
<tr>
<td>• Contributing from multiple viewpoints</td>
</tr>
<tr>
<td>• Inviting to dialog</td>
</tr>
<tr>
<td>• The voice of medication users</td>
</tr>
<tr>
<td>Learning by sharing</td>
</tr>
<tr>
<td>• Acknowledging each other’s daily life</td>
</tr>
<tr>
<td>• Creating shared understanding</td>
</tr>
<tr>
<td>• Reaching coherence</td>
</tr>
<tr>
<td>Mastering a digital space</td>
</tr>
<tr>
<td>• Meeting remotely is the future</td>
</tr>
<tr>
<td>• Building relationships remotely</td>
</tr>
<tr>
<td>• Structuring the work</td>
</tr>
<tr>
<td>• Digital hassles</td>
</tr>
<tr>
<td>• Allocating time</td>
</tr>
</tbody>
</table>

The voice of medication users stood out and was considered to be of extra importance, meaning that services in health care must be adjusted to make sense for both patients and health care professionals. Some health care professionals even highlighted that older persons should have had even more impact than they had in the co-design initiative. In contrast, the older persons thought that health care staff’s requirements must outweigh, as medication plans mainly concerned their way of working in daily practice. They also stated that they as patients had a responsibility to contribute to improving health care:

> And I think so…patient’s own responsibility. I would like to mention that. You cannot be passive in healthcare. Because then you are gone very quickly. You have to be…uh, at the forefront, updated, inquisitive. Ask uncomfortable questions. And you want an answer. [Interview—older person]

Although it was emphasized by the health care professionals that the older persons in this initiative were particularly knowledgeable, that is, “expert patients,” there were also concerns that the balance between patients and health care professionals might be to the disadvantage of the patients. Older persons might be frail, and medical terms and jargon in discussions can make it difficult for them to be completely involved.

Learning by sharing highlights the dynamic process of learning and understanding by sharing daily life experiences and realizing that despite different backgrounds, participants could reach consensus about the requirements for a medication plan.

Gaining knowledge about how things work out in different contexts and to acknowledge each other’s daily life was experienced as fruitful, meaning that the participants may not normally be aware of the situations of other patients or health care professionals:

> You get an insight into each other’s practice and can jointly reach something that works for everyone. [Survey—nurse]

The fictitious cases used in the workshops, whether the participants considered them familiar or not, worked out well for participants to reflect upon. The sharing of each other’s everyday practices contributed to individual learning and showed how other participants looked at the difficulties associated with medications. This learning provided insight into the desirable requirements for the medication plan and also into the challenges to come, such as medication prescribers having enough time when introducing a new way of working together.

Having a 2-way dialog with the possibility of providing direct responses to one another helped in creating shared understanding. The participants saw creating something together as valuable and good, meaning that it supported the development of the prototype:

> Yes, it [cocreation] is that people with different experiences, different lengths of experience, get the opportunity to work together and learn from each other. And build…build something together with…the platforms you have. [Interview—older person]

Participating in a dialog appeared to increase interest in the topic itself, generating increased curiosity about medication treatment in general. This approach was also considered worth applying to other improvement initiatives. However, concerns about missing out on the perspectives of groups other than those included, such as homecare staff and pharmacists, were raised, meaning that home health assistants (who were not represented in the co-design initiative) have valuable additional insights into everyday practice close to older persons.

The participants were reaching coherence for the final prototype, meaning that they seemed to empathize with each other’s needs to make the prototype applicable:
There was consensus around it. And I think that is also a very good thing about co-creation, that...just that we realize that there is a consensus.

[Interview—older person]

The prototype corresponded well with participants’ needs and expectations. They stated that it also seemed to live up to the requirements of the group as a whole. Understanding that different visions are not always profession related but person related was another experience the participants seemed to gain, as they observed that there appeared to be no “us and them.” Similarities in how to manage things applied to people, not profession.

Mastering a digital context focuses on the balance between opportunities and challenges the digital platform offers, such as building an inviting and creative environment for co-design in a web-based context.

Participants argued that meeting remotely is the future, as easy access from home or the workplace leads to efficient meetings:

Yes, many times, you have slightly more pithy comments and you listen a little more to others as well. [Interview—general practitioner]

The digital platform made it possible to join without losing valuable working hours traveling. The accessible platform was considered a proper alternative even after meeting restrictions, imposed during the COVID-19 pandemic, were lifted. The digital space provided ample room for reasoning and possibilities to interact in other ways, for instance, via digital chat.

Textbox 2. Transcription from a breakout room in workshop 2 (P=older person and F=facilitator)

P: Question from X [name]. I wonder, how many of us are in our group?
F: You are four in your group.

P: There are four of us? Yes, that is good. It is a new outfit today, so you never know…
F: Exactly. Y [name] is a nurse. Z [name] is a doctor. And X [name] and W [name] are users of medications.

Textbox 3. Transcription from a breakout room in workshop 1 (P=older person and F=facilitator)

F: Well I think...he probably managed to press ‘Join’ there. So we will...we will wait...we are waiting for some more to come. It is two more…
P: Yes.
F: We will see if she succeeds with that...Or what happens. But we can start a little bit then...There comes x [name] too. Welcome.

Some participants had more problems than others, and guidance was often required to resolve these situations. This could take extra time and contribute to some participants missing parts of the workshop.

Allocating time for cocreation was experienced as essential, meaning that during the workshops time seemed to pass quickly, whereas having time for discussion and reflection was considered important for the outcome. Worries were raised that time was hardly ever adjusted for difficult issues such as those in this initiative. Some participants also argued that more time would have helped older persons to provide input.

At the same time, building relationships remotely seemed to be more difficult, as the context challenges the way we normally build relationships. For example, the participants commented that informal chats during a coffee break, which help people get to know each other, were hard to imitate digitally. Moreover, having all faces side by side on a screen made it difficult to remember who was who and what role the person had (Textbox 2).

Knowing if someone was behind a “black screen”; the interpretation of silence in the digital room; and etiquette, such as knowing when to speak or not, seemed to be more complicated remotely, thereby hampering social interaction.

Structuring the work, such as moderating and giving clear instructions before and during each session, was desirable according to the participants and something they reported experiencing. The structure and quality of the workshops seemed to be related to the facilitators’ ability to provide guidance and instructions to the participants, for example, how to mute the microphone, answer Zoom Polls, or get in and out of breakout rooms. At the beginning of the process, some participants experienced that they did not know what was expected of them, which created uncertainty, but the support they received at the start made them feel comfortable and on track.

Technical problems, such as not being able to connect to workshops in time, not being able to present the right screen, or not understanding how to manage the digital room, contributed to digital hassles (Textbox 3).

Discussion

**Principal Findings**

User involvement in initiatives aiming at supporting patient safety is novel. Therefore, this study describes a remote co-design initiative, including both older persons and health care professionals, and highlights the experiences of the approach. Our findings indicate that remote co-design can be a complement or substitute for face-to-face co-design sessions but requires careful planning and adjustments in action throughout the process to allocate sufficient time for cocreation. Even so, the approach allowed an accessible environment for the participants, and the chosen co-design framework seemed to work well in a digital context. The participants had a positive
experience of participating in the co-design initiative and thought it allowed a permissive environment where everyone’s perspectives mattered. Sharing of everyday life created learning and resulted in the participants gaining awareness of possible risks and strategies that could contribute to safer medication treatment.

**Comparison of Data and Comparison With Previous Work**

In the quantitative results, participants rated the overall experience of the second workshop lower than the first, and the time for individual reflections in the second workshop was shorter than planned. In addition, the thematic analysis identified that participants considered time for dialog important and that lack of time could be a limitation, especially for older persons. To the best of our knowledge, the optimal duration of a co-design session is unknown. The time frames for these workshops were therefore a prediction, limiting the risk of digital fatigue [23], while allocating enough time for interaction and achieving adequate input on the prototype. The participants in this study experienced that they had the opportunity within the given time frame to hear and respond to others’ input directly. To find time for co-design is a matter of discussion, as co-design generally requires more time compared with top-down approaches, such as individual or group interviews, used to inform the design of a service [20,35]. Using participants’ time efficiently is advantageous, especially because a high workload makes it difficult to engage health care professionals in co-design initiatives [36]. The remote approach made it possible to participate without spending time on travel. Apart from saving time, remote initiatives may broaden participant groups, inviting those who really want to participate instead of only those who have the capacity and time to attend physical meetings [23,24]. Previous studies have shown that remote co-design has pros and cons [23,24], and this study revealed that digital hassles took time and adversely affected the timetable. Even so, managing new technology is not limited to aspects of age [37]. Individual user perspectives are more important to address than chronological age and are worth paying attention to in future remote co-design initiatives.

Even if the time allocated for cocreation might have been short, participants reported that they had opportunities to speak as much as they wanted. The workshop structure, guided by the Double Diamond framework, and the digital context seemed to form a welcoming environment, where facilitators and participants together created a space for the exchange of perspectives and ideas where everyone was empowered to speak and provide input. This mirrors another co-design study from Australia [23], suggesting that the web-based meeting space may break down power imbalances and establish equal participation. Facilitators can balance power between participants and encourage vulnerable members in a group to express their opinions [38]. As in many other co-design activities [39], the facilitators and participants in this initiative had no specific training in co-design. Nevertheless, our findings show that the participants were satisfied with the facilitation both during workshops and in between.

Both health care professionals and older persons in this study emphasized the importance of considering the views of patients when creating new services or products. However, the findings included statements that health care staff’s requirements must be more important than those of patients and also revealed concerns that building relationships remotely can be more challenging than face-to-face meetings. To constantly reflect on power relations in co-design initiatives is therefore essential to empower a balanced relationship between involved persons [15,40]. Future remote co-design initiatives conducted in the context of patient safety need to anticipate this, as an imbalance between patients and health care professionals may threaten the outcome. If health care organizations invite patients to co-design, health care professionals must share power with them and work responsibly to overcome barriers on equal terms [41].

On the basis of the results of this study, we cannot determine whether a remote co-design initiative with older persons supports patient safety. The participants experienced individual learning during the initiative, and by allowing patients, together with health care professionals, to address safety concerns, they might gain higher awareness of risks in their everyday life [42]. Other studies have shown that patients actively involved as co-creators of resilience at the micro, meso, and macro levels develop their own strategies to reduce harm and use their capabilities to contribute to safer care [43,44]. Patient participation in initiatives aimed at improving patient safety is still insufficiently explored, possibly because of challenges that arise when trying to involve patients in the complexity of health care processes [11]. Sharing of everyday practice provided the participants with insights into why special requirements were called for in the medication plan and also revealed possible challenges for future implementation. In approaches aimed at improving health care quality and patient safety, it is important to address organizational human factors and encourage the active and adaptive role of users [45]. The Systems Engineering Initiative for Patient Safety is a human factors systems approach to patient safety, which acknowledges the importance of considering the whole system for an intervention to have a sustainable impact on patient safety [45,46]. The participants in this initiative, representing different parts of the health care system, experienced that they contributed to the development of the prototype from multiple perspectives, such as patients and health care professionals. Their shared understanding, developed through this process, contributed to their common view of what was needed for the prototype to work well for everyone. Therefore, we conclude that co-design initiatives that include everyone’s perspectives and create learning for those involved may, also in a remote approach, inform the development of new products or services to improve patient safety.

**Strengths and Limitations**

We aimed to ensure trustworthiness, credibility, confirmability, dependability, and transferability were considered throughout this case study [47]. The case study design, with a thorough description of the initiative and using well-known qualitative and quantitative methods, contributed to *dependability* of the results. To ensure consistency, a pilot test of the setup for the workshops was conducted and evaluated, resulting in some
minor adjustments in the timetable. The first author performed all interviews with a semistructured interview guide to promote consistency.

Owing to the broad approach to recruiting participants, it is unknown how many people choose not to participate and why. We aimed for a mix of older persons, next of kin, and health care professionals [28], which was achieved, except that no persons participated solely as next of kin. The participants were recruited within the initiative Patient Contract and may therefore be prone to working together to strengthen the patients’ role in health care. In addition, older persons may be considered extra knowledgeable, and they had previous experience with digital meetings. Persons unable to communicate in Swedish or use a computer were therefore not included in this initiative, and concerns that digital initiatives may exclude some people have been raised before [23]. Consequently, the inclusion criteria used in this initiative need to be considered when interpreting the results, as they may affect transferability to other co-design initiatives with older persons.

Objectivity is important when considering the confirmability of data. The first author and one quality improvement adviser guided and facilitated the co-design initiative. Both had met some of the participants before in other projects, meaning they were known to each other. To ensure objectivity in the study findings, peer debriefing was used in the thematic analysis, where the first and last authors first reviewed themes together and then presented them to the author group to rewrite the final descriptions. The quality improvement adviser was not involved in the data analysis.

We believe that the multidisciplinary author group, with different experiences in patient safety and co-design, contributed to the study’s credibility, as preunderstanding is helpful in case studies and when interpreting if the findings are real and accurate. Linking and comparing our findings with each other and prior research also ensured the accuracy of our findings.

Future Directions
This remote co-design initiative has resulted in a medication plan prototype. A future study could address the last phase in the Double Diamond framework, the Deliver phase, and evaluate the medication plan prototype according to usability and safety.

Future studies could also expand on the remote co-design approach’s possibilities to broaden the participant group and increase opportunities for older people and health care professionals to meet and collaboratively improve patient safety. The web-based meeting space seems to support an inviting environment and establish equal participation, which allows participants to address safety concerns and contribute to safer care. Therefore, research to increase knowledge on how patients can be further involved in remote co-design initiatives aimed at improving patient safety would be helpful.

Conclusions
Participants experienced that the remote co-design initiative was inclusive of their perspectives and facilitated learning by sharing experiences. The Double Diamond framework was applicable in a digital context and supported the co-design process of the medication plan prototype. Remote co-design is still novel, but with attentiveness to power relations between all involved, this approach may increase opportunities for older persons and health care professionals to collaboratively design products or services that can improve patient safety.

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Data Availability
The data generated during this study are available from the corresponding author upon reasonable request.

Authors’ Contributions
All authors contributed to the design of the study and the discussion of the results and approved the final manuscript. MH and BL arranged the setup for the co-design initiative together with a quality improvement adviser in Region Jönköping County. MH participated in the workshops, performed the interviews, analyzed the data, and drafted and revised the manuscript. LJ supervised and helped with the analysis and interpretation of the data and reviewed the manuscript. JT, AR, and BL helped with the interpretation of the data and reviewed and edited the manuscript.

Conflicts of Interest
None declared.

Multimedia Appendix 1
Survey.
[DOCX File, 29 KB - aging_v6i1e41950_app1.docx ]
Multimedia Appendix 2
Timetable with planned activities.

[DOCX File, 29 KB - aging_v6i1e41950_app2.docx]

Multimedia Appendix 3
Interview guide.

[DOCX File, 22 KB - aging_v6i1e41950_app3.docx]

References


39. Donetto S, Tsianakas V, Robert G. Using Experience-Based Co-design (EBCD) to Improve the Quality of Healthcare: Mapping Where We Are Now and Establishing Future Directions. London, UK: King’s College London; 2014.


Abbreviations

ADE: adverse drug event

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The Changes in Levels and Barriers of Physical Activity Among Community-Dwelling Older Adults During and After the Fifth Wave of COVID-19 Outbreak in Hong Kong: Repeated Random Telephone Surveys

Zixin Wang¹*, PhD; Yuan Fang², PhD; Paul Shing-Fong Chan¹, MEd; Fuk Yuen Yu¹, MSSC; Fenghua Sun²*, PhD

¹Jockey Club School of Public Health and Primary Care, Chinese University of Hong Kong, Hong Kong, Hong Kong
²Department of Health and Physical Education, The Education University of Hong Kong, Hong Kong, Hong Kong
*these authors contributed equally

Corresponding Author:
Zixin Wang, PhD
Jockey Club School of Public Health and Primary Care
Chinese University of Hong Kong
Room 508, School of Public Health, Prince of Wales Hospital
Ngan Shing St, Sha Tin
Hong Kong
Hong Kong
Phone: 852 22528740
Email: wangzx@cuhk.edu.hk

Abstract

Background: COVID-19 has had an impact on physical activity (PA) among older adults; however, it is unclear whether this effect would be long-lasting, and there is a dearth of studies assessing the changes in barriers to performing PA among older adults before and after entering the “postpandemic era.”

Objective: The aim of this study was to compare the levels and barriers of PA among a random sample of community-dwelling older adults recruited during (February to April 2022) and after the fifth wave of the COVID-19 outbreak (May to July 2022) in Hong Kong. In addition, we investigated factors associated with a low PA level among participants recruited at different time points.

Methods: This study involved two rounds of random telephone surveys. Participants were community-dwelling Chinese-speaking individuals aged 65 years or above and having a Hong Kong ID card. Household telephone numbers were randomly selected from the most updated telephone directories. Experienced interviewers carried out telephone interviews between 6 PM and 10 PM on weekdays and between 2 PM and 9 PM on Saturdays to avoid undersampling of working individuals. We called 3900 and 3840 households in the first and second round, respectively; for each round, 640 and 625 households had an eligible older adult and 395 and 370 completed the telephone survey, respectively.

Results: As compared to participants in the first round, fewer participants indicated a low level of PA in the second round (28.6% vs 45.9%, \(P<.001\)). Participants in the second round had higher metabolic equivalent of tasks-minutes/week (median 1707.5 vs 840, \(P<.001\)) and minutes of moderate-to-vigorous PA per week (median 240 vs 105, \(P<.001\)) than those in the first round. After adjustment for significant background characteristics, participants who perceived a lack of physical capacity to perform PA (first round: adjusted odds ratio [AOR] 3.34, \(P=.001\); second round: 2.92, \(P=.002\)) and believed that PA would cause pain and discomfort (first round: AOR 2.04, \(P=.02\); second round: 2.82, \(P=.001\)) were more likely to have a low level of PA in both rounds. Lack of time (AOR 4.19, \(P=.01\)) and concern about COVID-19 infection during PA (AOR 1.73, \(P=.02\)) were associated with a low level of PA among participants in the first round, but not in the second round. A perceived lack of space and facility to perform PA at home (AOR 2.03, \(P=.02\)) and unable to find people to do PA with (AOR 1.80, \(P=.04\)) were associated with a low PA level in the second round, but not in the first round.

Conclusions: The level of PA increased significantly among older adults after Hong Kong entered the “postpandemic era.” Different factors influenced older adults’ PA level during and after the fifth wave of the COVID-19 outbreak. Regular monitoring of the PA level and its associated factors should be conducted to guide health promotion and policy-making.
KEYWORDS
COVID-19; physical activity; older adults; barriers; changes; repeated random telephone survey; China; aging; elderly population; community-dwelling older adults; health promotion; telehealth

Introduction

Hong Kong has a rapidly aging population. By 2030, 22% of Hong Kong residents will be ≥65 years old [1]. Recent data show that 75% of older adults in Hong Kong are suffering from one or more chronic diseases [1]. This situation has already created a huge burden on the local health system [1]. Physical activity (PA) is defined as any bodily movement produced by the skeletal muscles that results in an expenditure of energy, and is widely recognized as an effective intervention for reducing mortality and the risk of dependence-inducing diseases in older adults [2]. Systematic reviews have shown that sustainable PA improved cognitive functions, frailty symptoms, body composition, and physical functions among older adults [3,4]. Therefore, the World Health Organization (WHO) recommends that older adults without any contradiction to PA should perform at least 150 minutes of moderate-intensity aerobic PA, at least 75 minutes of vigorous-intensity aerobic PA, or an equivalent combination of moderate-to-vigorous PA (MVPA) every week [2]. Local health authorities follow the same recommendation.

Physical inactivity remains a global phenomenon and increases significantly with age. A systematic review showed that 43.4%-78.0% of older adults across countries could not meet the WHO-recommended PA level [5]. In Hong Kong, the prevalence of physical inactivity was 13.5% among people aged 65-74 years, 22.4% among those aged 75-84 years, and 42.8% among those aged 85 years or above in 2019 [6]. Another study conducted in Hong Kong before the COVID-19 outbreak reported that 20% of individuals aged ≥60 years had a low PA level [7]. Globally, the COVID-19 pandemic has negatively affected PA levels among older adults [8]. As compared to the time before COVID-19, studies consistently observed a decline in PA level among older adults after the COVID-19 outbreak [9-18]. Similar trends were observed in Hong Kong. As compared to the PA situation in 2019, two studies found a decline in the frequency of walking and moderate- and high-intensity sports among the general population, and in the overall PA level among men aged ≥60 years after the COVID-19 outbreak [10,19]. Therefore, there is an urgent need to improve PA among older adults in Hong Kong, especially considering the negative impact of COVID-19.

Several different facilitators and barriers affect the participation of PA among older adults. A systematic review suggested that lack of knowledge, skills, capacities, and support from peers or family members related to PA; perceived cons of PA (causing pain, risk of injury, and fear of falling); and environmental barriers (access to facilities and transportation, bad weather) were the main barriers of performing PA among community-dwelling older adults [20]. Perceived benefits of PA (improved physical and mental health, fun and enjoyment), perceived self-efficacy, and suggestions from health professionals were highlighted as facilitators [20]. Similar facilitators and barriers applied to Hong Kong older adults before the COVID-19 outbreak [7]. During the outbreak, COVID-19 control measures (closure of exercise facilities, social distancing) significantly increased older adults’ difficulties in accessing sports facilities and reduced support from peers [8]. An increase in caring responsibility during the pandemic due to school closure further reduced the availability for PA [21]. Moreover, concerns about the risk of COVID-19 infection reduces older adults’ motivation, and increases fear and anxiety related to PA [8,16,18]. Achieving “zero-COVID” is difficult. Instead, most countries have started to relax COVID-19 control measures and “return to normal” with high COVID-19 vaccination coverage. In Hong Kong, the government lifted its strict COVID-19 control measures (e.g., closure of schools and sports facilities, prohibiting group gatherings) when the number of daily new cases dropped to about 300 (April 2022) [22]. Despite an increasing trend of daily confirmed COVID-19 cases (from <300 in May 2022 to over 3000 in July 2022), the government did not tighten up COVID-19 control measures again [22]. The changing pandemic and its control measures might influence barriers to performing PA among older adults. To our knowledge, it remains unclear whether the impact of COVID-19 on PA among older adults would be long-lasting, and there is a dearth of studies assessing the changes in barriers to performing PA among older adults before and after entering the “postpandemic era.”

To address the above-mentioned knowledge gaps, we analyzed the data of two rounds of cross-sectional random telephone surveys among community-dwelling older adults in Hong Kong, China. We compared levels and barriers to performing PA between rounds. In addition, we investigated the factors associated with a low PA level among participants of different rounds. We hypothesized that less participants would have a low PA level in the second round of the survey compared to the first round. Associated factors of low PA level were also expected to be different between the two rounds of the survey.

Methods

Study Design

This study was a secondary analysis of two rounds of random telephone surveys investigating COVID-19 vaccination uptake among community-dwelling Chinese-speaking individuals aged 65 years or above in Hong Kong, China [23]. STROBE checklist for cross-sectional study was shown in Multimedia Appendix 1. The first round was conducted during the fifth wave of the COVID-19 outbreak between February 14 and April 13, 2022. During the first round, strict COVID-19 control measures were implemented [24], including (1) closure of all playgroups, kindergartens, and primary schools (between January 14 and April 19, 2022); (2) closure of fitness centers, swimming pools, and sports premises (between January 5 and April 21, 2022);
and (3) prohibition of social gatherings involving more than two persons (between February 8 and April 21, 2022). The number of daily confirmed COVID-19 cases reached its peak on March 2, 2022 (n=56,827) and dropped to 1043 on April 13, 2022. The second round of telephone surveys was conducted between May 11 and July 11, 2022. The number of daily confirmed COVID-19 cases increased slowly from 294 on May 11, 2022, to 2769 on July 11, 2022. A summary of the COVID-19 situation and its control measures in Hong Kong during the study period is presented in Figure 1.

**Figure 1.** The COVID-19 situation and its control measures in Hong Kong during the study period.

### Participants and Data Collection

Inclusion criteria of the participants were: (1) community-dwelling Chinese-speaking individuals aged 65 years or above and (2) having a Hong Kong ID card. The exclusion criterion was not able to communicate effectively with the study interviewers. We used the same data collection methods in both rounds of surveys and reported these details previously [23]. First, we input all household telephone numbers listed in the most updated telephone directories (approximately 350,000) into an Excel file. We then randomly selected 4000 numbers by using the function “select random cells.” Experienced interviewers carried out telephone interviews between 6 PM and 10 PM on weekdays and between 2 PM and 9 PM on Saturdays to avoid undersampling of working individuals. We considered a household to be nonvalid (one without an eligible participant) if no one answered five calls made at different time slots. If there was more than one individual in the household who was 65 years or above, the interviewers invited the person whose last birthday was the closest to the survey date to join the study. This practice was adopted to avoid clustering effects (ie, older adults living in the same household sharing a similar PA level and determinants of PA). Interviewers screened prospective participants for eligibility; briefed them about the study; and made guarantees of anonymity, their right to quit at any time, and that refusal to participate would have no consequences. Verbal informed consent was obtained. The interviewers also signed a form pledging that the participants had been fully informed about the study. The telephone interview took approximately 20 minutes to complete. No incentives were given to the participants.

### Ethics Approval

Ethics approval was obtained from the Survey and Behavioral Research Ethics Committee of the Chinese University of Hong Kong (SBRE-19-187).

### Measures

#### Background Characteristics

The English and Chinese versions of the questionnaires are provided in Multimedia Appendix 2. Participants reported sociodemographic characteristics (eg, age, sex assigned at birth, relationship status, education level, employment status, income, and living arrangement), presence of chronic diseases, and history of COVID-19 and COVID-19 vaccination.

#### PA Assessment

The interviewers assessed participants’ PA in the past week using the validated Chinese version of the 7-item International Physical Activity Questionnaire-Short Form (IPAQ-SF) [25]. The IPAQ-SF was validated in Chinese older adults [26,27]. The questionnaire assessed the walking, and moderate- and
vigor-intensity activities of an individual in the past week. We computed the metabolic equivalent of tasks (MET) minutes per week and minutes of MVPA per week, and categorized the PA levels into high, moderate, and low based on the protocol of IPAQ-SF [25]. A high level of PA was defined as (1) vigorous-intensity activity on at least 3 days achieving a minimum total PA of ≥1500 MET-minutes/week or (2) ≥7 days of any combination of walking or moderate- or vigorous-intensity activities achieving a minimum total PA of ≥3000 MET-minutes/week. A moderate PA level was defined as: (1) ≥3 days of vigorous-intensity activity of at least 20 minutes per day, (2) ≥5 days of moderate-intensity activity and/or walking of at least 30 minutes per day, or (3) ≥5 days of any combination of walking and moderate-intensity or vigorous-intensity activities achieving a total PA of 600 MET-minutes/week. Participants who did not meet the criteria of a moderate or high level of PA were considered to have a low PA level.

**Barriers to Performing PA**

Nine items were constructed for this study to assess barriers to performing PA (response categories: 1=disagree, 2=neutral, and 3=agree). They were: (1) do not have time, (2) lack of interest, (3) cannot find people to do PA with, (4) lack of physical capacity to do PA, (5) PA will cause pain and discomfort, (6) lack of space and facility to do PA at home, (7) concern about COVID-19 infection during PA, (8) closure of facilities due to COVID-19 and its control measures, and (9) peers refused to do PA with you due to COVID-19. Responses to these items were dichotomized (“disagree/neutral” vs “agree”) for analysis.

**Sample Size Determination**

The target sample size for each round of the survey was 400. The sample size planning for the original study was explained in a previous publication [23]. In brief, assuming the proportion of participants having a low PA level of 30%-70% in the first round, this sample size was determined to be sufficient to detect a minimum between-round difference of 8.6% (power=0.80, α=.05; calculated with PASS 11.0 software).

**Statistical Analysis**

There were no missing values in either round of survey. The differences in background characteristics between participants in the first and second rounds were assessed using $\chi^2$ tests. After controlling for background variables with significant differences between rounds, the differences in the level of PA, MET-minutes/week, minutes of MVPA per week, and barriers to performing PA were compared using ordinal, logistic, or linear regression models. The level of PA, MET-minutes/week, and minutes of MVPA per week between rounds were further compared in subgroups of participants with and without a specific barrier to performing PA (ie, lack of physical capacity to perform PA or perception that PA would cause pain and discomfort). The subsequent analysis was performed among participants in the same round of the survey. Using a low level of PA as the dependent variable and background characteristics as independent variables, crude odds ratios were obtained using logistic regression models. The associations between barriers to performing PA and the dependent variable were then obtained by fitting a single logistic regression model involving one of the independent variables and all significant background characteristics. Adjusted odds ratios (AORs) and respective 95% CIs were obtained. SPSS version 26.0 (IBM Corp, Armonk, NY, USA) was used for data analysis, with $P<.05$ considered as statistically significant.

**Results**

**Background Characteristics**

We called 3900 and 3840 households in the first and second rounds, 640 and 625 households had an eligible older adult, 245 and 255 refused to participate in the study, and 395 and 370 completed the telephone survey, respectively. The response rate was 62% and 59% in the first and second round, respectively. The characteristics of the participants are presented in Table 1. Approximately half of the participants were aged 70 years or above (first round, 50.1%; second round, 50.8%) and female. Most of the participants were married or cohabited with a partner, did not receive tertiary education (first round, 89.9%; second round, 89.2%), without full-time/part-time employment, and with a monthly household income lower than HK $20,000 (US $2580). Approximately one-fifth of the participants had at least one chronic condition (first round, 19.2%; second round, 18.9%). There was no difference in these characteristics between participants in the first and second rounds ($P$ values ranged from .68 to .98). As compared to participants in the first round, more participants in the second round reported a history of COVID-19, completed the primary COVID-19 vaccination series (92.1% vs 78.7%, $P<.001$), and had received COVID-19 vaccine booster doses (58.9% vs 31.6%, $P<.001$).
Table 1. Background characteristics of the participants.

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<tr>
<th>Characteristics</th>
<th>Round 1 (n=395), n (%)</th>
<th>Round 2 (n=370), n (%)</th>
<th>P value</th>
</tr>
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<td><strong>Sociodemographic characteristics</strong></td>
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<td>Age group (years)</td>
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<td>70-74</td>
<td>132 (33.4)</td>
<td>125 (33.8)</td>
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<td>63 (17.0)</td>
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<td>145 (39.2)</td>
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<td>238 (60.3)</td>
<td>225 (60.8)</td>
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<td>94 (25.4)</td>
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<td>Married or cohabiting</td>
<td>298 (75.4)</td>
<td>276 (74.6)</td>
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<td>Education level</td>
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<tr>
<td>Primary or below</td>
<td>167 (42.3)</td>
<td>157 (42.4)</td>
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<td>Secondary</td>
<td>188 (47.6)</td>
<td>173 (46.8)</td>
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</tr>
<tr>
<td>Tertiary or above</td>
<td>40 (10.1)</td>
<td>40 (10.8)</td>
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<td>Current employment status</td>
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<td>Unemployed/retired/homemaker</td>
<td>339 (85.8)</td>
<td>319 (86.2)</td>
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<td>Full-time/part-time</td>
<td>56 (14.2)</td>
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<td>&lt;20,000 (2580)</td>
<td>292 (74.3)</td>
<td>273 (74.2)</td>
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<tr>
<td>≥20,000 (2580)</td>
<td>53 (13.5)</td>
<td>49 (13.3)</td>
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<tr>
<td>Refuse to disclose</td>
<td>48 (12.2)</td>
<td>46 (12.5)</td>
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<td>364 (92.2)</td>
<td>342 (92.4)</td>
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<td>Yes</td>
<td>31 (7.8)</td>
<td>28 (7.6)</td>
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<td>Living alone</td>
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<td>No</td>
<td>328 (83.0)</td>
<td>304 (82.2)</td>
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<td>67 (17.0)</td>
<td>66 (17.8)</td>
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<td>Medical history</td>
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<td>Presence of chronic conditions, yes</td>
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<td>Hypertension</td>
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<td>173 (46.8)</td>
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<td>Chronic cardiovascular diseases</td>
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<td>40 (10.8)</td>
<td>.97</td>
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<td>Chronic lung diseases</td>
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<td>6 (1.6)</td>
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<td>Chronic liver diseases</td>
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<td>8 (2.2)</td>
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<td>Chronic kidney diseases</td>
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<td>2 (0.5)</td>
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<td>Diabetes mellitus</td>
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<td>70 (18.9)</td>
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<td>Any of above</td>
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<td>History of COVID-19</td>
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<tr>
<td>No</td>
<td>353 (89.4)</td>
<td>276 (74.6)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>42 (10.6)</td>
<td>94 (25.4)</td>
<td></td>
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<tr>
<td>Number of doses of COVID-19 vaccination received</td>
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</tr>
<tr>
<td>0</td>
<td>32 (8.1)</td>
<td>16 (4.3)</td>
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| Wang et al | JMIR AGING 2023 | vol. 6 | e42223 | p.562 | XSL•FO RenderX | https://aging.jmir.org/2023/1/e42223 | JMIR Aging 2023 | vol. 6 | e42223 | p.562 | (page number not for citation purposes) |
Changes in PA

The changes in PA are presented in Table 2. As compared to participants in the first round, fewer participants had a low level of PA in the second round. Participants in the second round had higher MET-minutes/week and minutes of MVPA per week than those in the first round. Subgroup analysis showed that older adults with some specific barriers to performing PA (i.e., lack of physical capacity or perceived that PA would cause pain and discomfort) had a significantly lower PA level, MET-minutes/week, and minutes of MVPA per week compared to those of participants without such barriers (see Multimedia Appendix 3).
Table 2. Physical activity and barriers to performing physical activity.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Round 1 (n=395)</th>
<th>Round 2 (n=370)</th>
<th>P value</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
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<tbody>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Level of physical activity, n (%)</td>
<td></td>
<td></td>
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<tr>
<td>Low</td>
<td>170 (45.9)</td>
<td>106 (28.6)</td>
<td>&lt;.001</td>
<td>&lt;.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>147 (39.7)</td>
<td>161 (43.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>53 (14.3)</td>
<td>103 (27.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MET&lt;sup&gt;b&lt;/sup&gt;-minutes/week, median (IQR)</td>
<td>840.0 (371.3-1834.3)</td>
<td>1707.5 (716.6-3395.0)</td>
<td>&lt;.001</td>
<td>&lt;.001&lt;sup&gt;c&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Minutes of moderate-intensity or vigorous-intensity physical activity (MVPA) per week, median (IQR)</td>
<td>105 (0-315)</td>
<td>240 (67.5-600)</td>
<td>&lt;.001</td>
<td>&lt;.001&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Barriers to performing physical activity, n (%)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Do not have time</td>
<td></td>
<td></td>
<td>.18</td>
<td>.08&lt;sup&gt;d&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Disagree/neutral</td>
<td>368 (93.2)</td>
<td>353 (95.4)</td>
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<tr>
<td>Agree</td>
<td>27 (6.8)</td>
<td>17 (4.6)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lack of interest</td>
<td></td>
<td></td>
<td>.08</td>
<td>.12&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Disagree/neutral</td>
<td>342 (86.6)</td>
<td>303 (81.9)</td>
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<tr>
<td>Agree</td>
<td>53 (13.4)</td>
<td>67 (18.1)</td>
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<tr>
<td>Cannot find people to do physical activity together</td>
<td></td>
<td></td>
<td>.73</td>
<td>.29&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
<td>Disagree/neutral</td>
<td>287 (72.7)</td>
<td>273 (73.8)</td>
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<tr>
<td>Agree</td>
<td>108 (27.3)</td>
<td>97 (26.2)</td>
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<tr>
<td>Lack of physical capacity to do physical activity</td>
<td></td>
<td></td>
<td>.58</td>
<td>.47&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Disagree/neutral</td>
<td>355 (89.9)</td>
<td>328 (88.6)</td>
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<tr>
<td>Agree</td>
<td>40 (10.1)</td>
<td>42 (11.4)</td>
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<tr>
<td>Physical activity will cause pain and discomfort</td>
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<td></td>
<td>.98</td>
<td>.83&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Disagree/neutral</td>
<td>335 (84.8)</td>
<td>314 (84.9)</td>
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<td></td>
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<tr>
<td>Agree</td>
<td>60 (15.2)</td>
<td>56 (15.1)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Lack of space and facility to do physical activity at home</td>
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<td></td>
<td>.04</td>
<td>.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Disagree/neutral</td>
<td>274 (69.4)</td>
<td>281 (75.9)</td>
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</tr>
<tr>
<td>Agree</td>
<td>121 (30.6)</td>
<td>89 (24.1)</td>
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<td></td>
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<tr>
<td>Concern about COVID-19 infection when doing physical activity</td>
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<td></td>
<td>&lt;.001</td>
<td>&lt;.001&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
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<tr>
<td>Disagree/neutral</td>
<td>118 (29.9)</td>
<td>189 (51.1)</td>
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</tr>
<tr>
<td>Agree</td>
<td>277 (70.1)</td>
<td>181 (48.9)</td>
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<td></td>
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<tr>
<td>Closure of facilities due to COVID-19 and its control measures</td>
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<td></td>
<td>.26</td>
<td>.046&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
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<td>232 (62.7)</td>
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<tr>
<td>Agree</td>
<td>163 (41.3)</td>
<td>138 (37.3)</td>
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<tr>
<td>Peers refused to do physical activity with you due to COVID-19</td>
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<td></td>
<td>.10</td>
<td>.01&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>Disagree/neutral</td>
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<td>244 (65.9)</td>
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<td>126 (34.1)</td>
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</table>

<sup>a</sup>P values obtained from multivariate ordinal logistic regression after adjusting for history of COVID-19 and number of doses of COVID-19 vaccination received.

<sup>b</sup>MET: metabolic equivalent of tasks.

<sup>c</sup>P values obtained from multivariate linear regression models after adjusting for history of COVID-19 and number of doses of COVID-19 vaccination received.
Changes in Barriers to Performing PA
The changes in barriers to performing PA are also presented in Table 2. As compared to participants in the first round, fewer participants in the second round reported lack of space and a facility to do PA at home or being concerned about COVID-19 infection when doing PA. Fewer participants had experienced the closure of facilities and refusal by peers to do PA with them due to COVID-19 compared to those in the first round.

Factors Associated With Having a Low PA Level
In univariate analysis, participants who completed the primary COVID-19 vaccination series and/or booster dose were less likely to have a low PA level in both rounds (Table 3). After adjustment for these significant characteristics, participants who perceived a lack of physical capacity to do PA and believed that PA would cause pain and discomfort were more likely to have low level of PA in both rounds. Do not have time and concern about COVID-19 infection during PA were associated with a low level of PA among participants in the first round, but not in the second round. Perceived lack of space and facility to do PA at home and cannot find people to do PA together were associated with a low PA level in the second round, but not in the first round (Table 4).
### Table 3. Associations between background characteristics and low physical activity level.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Round 1 (n=395)</th>
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<th>Round 2 (n=370)</th>
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<td>OR(^a) (95% CI)</td>
<td>(P) value</td>
<td>OR (95% CI)</td>
<td>(P) value</td>
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<td><strong>Age group (years)</strong></td>
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<tr>
<td>65-69 (reference)</td>
<td>1.0</td>
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<td>1.0</td>
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<tr>
<td>70-74</td>
<td>1.40 (0.90-2.19)</td>
<td>.14</td>
<td>0.96 (0.57-1.62)</td>
<td>.88</td>
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<tr>
<td>75 or above</td>
<td>1.32 (0.75-2.31)</td>
<td>.33</td>
<td>1.96 (1.08-3.58)</td>
<td>.03</td>
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<tr>
<td><strong>Sex assigned at birth</strong></td>
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<td>Male (reference)</td>
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<tr>
<td>Female</td>
<td>0.86 (0.58-1.29)</td>
<td>.48</td>
<td>0.98 (0.62-1.55)</td>
<td>.92</td>
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<td><strong>Relationship status</strong></td>
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<td>Currently single (reference)</td>
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<td>1.0</td>
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<tr>
<td>Married or cohabiting</td>
<td>1.13 (0.71-1.79)</td>
<td>.61</td>
<td>1.55 (0.89-2.68)</td>
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<td><strong>Education level</strong></td>
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<tr>
<td>Primary or below (reference)</td>
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<tr>
<td>Secondary</td>
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<td>1.26 (0.78-2.04)</td>
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<td>Tertiary or above</td>
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<tr>
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<td>1.0</td>
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<td>Full-time/part-time</td>
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<td>1.16 (0.61-2.21)</td>
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<td><strong>Monthly household income, HK $ (US $)</strong></td>
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<td>&lt;20,000 (2580) (reference)</td>
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<tr>
<td>≥20,000 (2580)</td>
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<td>.60</td>
<td>0.86 (0.43-1.70)</td>
<td>.66</td>
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<tr>
<td>Refuse to disclose</td>
<td>0.67 (0.36-1.26)</td>
<td>.21</td>
<td>0.66 (0.31-1.39)</td>
<td>.27</td>
</tr>
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<td><strong>Receiving CSSA(^c)</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>No (reference)</td>
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<tr>
<td>Yes</td>
<td>0.64 (0.30-1.36)</td>
<td>.24</td>
<td>0.39 (0.13-1.16)</td>
<td>.09</td>
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<tr>
<td><strong>Living alone</strong></td>
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<td></td>
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<tr>
<td>No (reference)</td>
<td>1.0</td>
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<tr>
<td>Yes</td>
<td>1.11 (0.66-1.88)</td>
<td>.69</td>
<td>0.92 (0.51-1.67)</td>
<td>.79</td>
</tr>
<tr>
<td><strong>Presence of any chronic conditions</strong></td>
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<tr>
<td>No (reference)</td>
<td>1.0</td>
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</tr>
<tr>
<td>Yes</td>
<td>0.87 (0.58-1.30)</td>
<td>.49</td>
<td>1.13 (0.71-1.79)</td>
<td>.62</td>
</tr>
<tr>
<td><strong>History of COVID-19</strong></td>
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<tr>
<td>No (reference)</td>
<td>1.0</td>
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<td>1.0</td>
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</tr>
<tr>
<td>Yes</td>
<td>0.99 (0.52-1.87)</td>
<td>.96</td>
<td>1.23 (0.74-2.05)</td>
<td>.42</td>
</tr>
<tr>
<td><strong>Number of doses of COVID-19 vaccination received</strong></td>
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<tr>
<td>0-1 (reference)</td>
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<td></td>
<td>1.0</td>
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<tr>
<td>2</td>
<td>0.59 (0.35-0.99)</td>
<td>.048</td>
<td>0.43 (0.19-0.99)</td>
<td>.049</td>
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<td>3-4</td>
<td>0.50 (0.29-0.88)</td>
<td>.02</td>
<td>0.48 (0.22-1.05)</td>
<td>.07</td>
</tr>
</tbody>
</table>

\(^a\)OR: odds ratio.  
\(^b\)Not applicable.  
\(^c\)CSSA: Comprehensive Social Security Assistance.
Our findings suggested some different barriers to performing PA applied to older adults in Hong Kong before and after the fifth wave of the outbreak. First, a higher proportion of older adults agreed that they did not have time for PA in the first round compared to those in the second round. Those who lacked time for PA were more likely to report a low PA level in the first round, but not in the second round. In Hong Kong, grandparents are the main caregivers of children [28,29]. A qualitative study suggested that the increased caring responsibility due to school closure and lack of childcare during the pandemic was a barrier to performing PA among older adults in the United Kingdom [21].

**Discussion**

**Principal Findings**

This was one of the first studies to track changes in the levels and barriers to performing PA among older adults before and after entering the “postpandemic era.” One of the strengths of this study is that it was based on a random and population-based sample. In response to the fifth wave of the COVID-19 outbreak, the Hong Kong government closed all sports centers and venues, and advised older adults to stay at home and limit their outdoor activities due to their vulnerability to COVID-19 [24]. Therefore, it was not surprising to observe that a sizeable proportion of older adults had a low PA level (over 40%), which was much higher than that reported at the time before COVID-19 (about 20%) [6,7]. Despite an increasing trend in daily confirmed cases, we observed a significant increase in PA level among older adults in the second round of the survey. However, the proportion of older adults having a low PA level (27.8%) was still higher than that reported at the time before COVID-19 (20%) [6,7]. Therefore, efforts are needed to facilitate older adults to resume and increase PA in the “postpandemic era.”

**Comparison With Prior Work and Implications for Health Promotion**

As compared to those in the first round, participants in the second round reported a much higher completion rate of the primary COVID-19 vaccine series (94% vs 78.7%) and the booster dose (58.9% vs 31.6%). Completing the primary COVID-19 series and/or the booster dose (58.9% vs 31.6%) was associated with a higher PA level in both rounds. An increase in COVID-19 vaccination coverage might contribute to the increasing PA level in the second round. Vaccinated older adults might feel they are protected against COVID-19 and hence have fewer concerns to resume outdoor activities (eg, PA). Promoting COVID-19 vaccination and the booster dose might be useful strategies to improve PA among older adults in the future.

### Table 4. Associations between perceived barriers to performing physical activity and low physical activity level.

<table>
<thead>
<tr>
<th>Perceived barriersa</th>
<th>Round 1 (n=395)</th>
<th>Round 2 (n=370)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AOR b (95% CI)</td>
<td>P value</td>
</tr>
<tr>
<td>Do not have time</td>
<td>4.19 (1.54-11.40)</td>
<td>.01</td>
</tr>
<tr>
<td>Lack of interest</td>
<td>1.06 (0.59-1.90)</td>
<td>.85</td>
</tr>
<tr>
<td>Cannot find people to do physical activity together</td>
<td>1.07 (0.68-1.67)</td>
<td>.78</td>
</tr>
<tr>
<td>Lack of physical capacity to do physical activity</td>
<td>3.34 (1.61-6.94)</td>
<td>.001</td>
</tr>
<tr>
<td>Physical activity will cause pain and discomfort</td>
<td>2.04 (1.15-3.61)</td>
<td>.02</td>
</tr>
<tr>
<td>Lack of space and facility to do physical activity at home</td>
<td>0.74 (0.48-1.14)</td>
<td>.17</td>
</tr>
<tr>
<td>Concern about COVID-19 infection when doing physical activity</td>
<td>1.73 (1.10-2.72)</td>
<td>.02</td>
</tr>
<tr>
<td>Closure of facilities due to COVID-19 and its control measures</td>
<td>0.97 (0.66-1.48)</td>
<td>.95</td>
</tr>
<tr>
<td>Peers refused to do physical activity with you due to COVID-19</td>
<td>1.45 (0.96-2.19)</td>
<td>.08</td>
</tr>
</tbody>
</table>

aResponses were categorized into disagree/neutral (reference category) and agree.
bAOR: adjusted odds ratio; adjusted for significant background characteristics listed in Table 3.
home-based PA without extensive requirement of space or facilities, such as stationary aerobic exercise or weight/strength training. Although the Hong Kong government used a series of exercise videos on television to promote PA at home for older adults living in public housing estates during the pandemic [30], the efficiency of such programs in promoting PA for older adults should be further explored. In addition, facilitating older adults to form peer support groups is a useful strategy to promote PA in the “postpandemic era.” Forming such peer support groups was less feasible during the pandemic when group gatherings were prohibited [24]. Since the government already lifted the restriction on group social gatherings, health promotion in the “postpandemic era” should consider using such a strategy [31].

Some similar barriers have hindered older adults to perform PA both before and after the fifth wave of the COVID-19 outbreak. In this study, concern about PA capacity and that PA would cause pain and discomfort were associated with a lower PA level. These concerns were also barriers to performing PA in this group before the time of COVID-19 [7,20]. Sport scientists should introduce feasible options of PA suitable for older adults. Testimonials of older adults on how they overcome these physical and environmental barriers and stay active might also be useful. Studies suggested that communication among Chinese older adults is very effective due to the high level of rapport among people of similar age [32]. Chinese older adults prefer to seek information and opinion from their peers, which are considered to be more credible than other information sources [32].

In contrast to our hypothesis, the closure of facilities due to COVID-19 and its control measures were not significantly associated with the PA level in the first or the second round. A previous study suggested that older adults in Hong Kong changed their mode of PA to cope with the COVID-19 control measures. For example, older adults reduced swimming or going to the gym for exercise, but increased stretching, brisk walking, or other activities that rely less on access to sports facilities [10]. Such adaptations might have mitigated the impact caused by the closure of sports facilities.

Limitations

This study had some limitations. First, it was a major limitation that we did not assess the functional limitations of the participants. In Hong Kong, 16.3% of community-dwelling older adults had a functional limitation [33]. Older adults with functional limitation had lower PA levels. Second, we did not gather more information on family members of the participants due to the limited length of the questionnaire. Family members would have an influence on participants’ PA level (eg, whether family members can share the childcare responsibility during school closure). Third, PA was self-reported. We did not use accelerometers or wearable devices to assess PA due to feasibility and resource constraints. This raised concerns about reliability and recall bias. Fourth, due to the limited length of the questionnaire, some determinants of PA among older adults were not covered by the study (eg, perceived benefits and self-efficacy of PA). Fifth, we did not measure participants’ physical capacity to perform PA. Sixth, compared to census data, people who were 75 years or above were undersampled in this study [34]. However, the distributions of gender and age were similar to those of recent random telephone surveys among community-dwelling older adults [35]. Furthermore, nonresponses would cause selection bias. We were not able to obtain characteristics of those who refused to participate, which might be different from those of the participants. Our response rate was comparable to those of previous random telephone surveys targeting older adults in Hong Kong [32,35,36]. Last but not least, this was a cross-sectional study and could not establish causal relationships.

Conclusion

The level of PA increased significantly after the drop of daily confirmed COVID-19 cases and the relaxation of COVID-19 control measures among older adults in Hong Kong. Different factors influenced older adults’ PA level during and after the fifth wave of the COVID-19 outbreak. Barriers to performing PA, such as perceived lack of space and a facility to perform PA at home, concerns about COVID-19 infection during PA, closure of facilities, and refusals made by peers to perform PA reduced significantly over time. Regular monitoring of the PA level and its associated factors should be conducted to guide health promotion and policy-making. Sport scientists should introduce suitable options for older adults with inadequate physical capacity or having functional limitations. In the “postpandemic era,” reactivating peer support groups and promoting home-based PA may increase the PA level among older adults. Health authorities should be aware of the negative impact of school closure on PA among older adults. If school closure has to be implemented in future waves of a COVID-19 outbreak, introducing PA options suitable for older adults to perform with their grandchildren may be helpful to alleviate its negative influence.

Acknowledgments

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Data Availability

The data sets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.
Conflicts of Interest
None declared.

Multimedia Appendix 1
STROBE checklist for cross-sectional study.
[DOCX File, 33 KB - aging_v61e42223_app1.docx ]

Multimedia Appendix 2
The English and Chinese versions of the questionnaires used in the telephone survey.
[DOCX File, 38 KB - aging_v61e42223_app2.docx ]

Multimedia Appendix 3
Changes in physical activity among subgroups of participants.
[DOCX File, 25 KB - aging_v61e42223_app3.docx ]

References


Pandemic-Related Changes in Technology Use Among a Sample of Previously Hospitalized Older Adult New Yorkers: Observational Study

Brittany F Drazich¹, RN, MSN, PhD; Ji Won Lee², CRNP, RN; Kathryn H Bowles³,⁴, RN, PhD; Janiece L Taylor², RN, MSN, PhD; Shivani Shah⁴, MPH; Barbara Resnick¹, CRNP, PhD; Nayeon Kim¹, RN; Sarah L Szanton²,⁵, ANP, PhD

¹School of Nursing, University of Maryland, Baltimore, MD, United States
²School of Nursing, Johns Hopkins University, Baltimore, MD, United States
³School of Nursing, University of Pennsylvania, Philadelphia, PA, United States
⁴Center for Home Care Policy & Research, VNS Health, New York City, NY, United States
⁵School of Public Health, Johns Hopkins University, Baltimore, MD, United States

Corresponding Author:
Brittany F Drazich, RN, MSN, PhD
School of Nursing
University of Maryland
655 W Lombard St
Baltimore, MD, 21201
United States
Phone: 1 410 706 0501
Email: brittdrazich@gmail.com

Abstract

Background: The COVID-19 pandemic increased the importance of technology for all Americans, including older adults. Although a few studies have indicated that older adults might have increased their technology use during the COVID-19 pandemic, further research is needed to confirm these findings, especially among different populations, and using validated surveys. In particular, research on changes in technology use among previously hospitalized community-dwelling older adults, especially those with physical disability, is needed because older adults with multimorbidity and hospital associated deconditioning were a population greatly impacted by COVID-19 and related distancing measures. Obtaining knowledge regarding previously hospitalized older adults’ technology use, before and during the pandemic, could inform the appropriateness of technology-based interventions for vulnerable older adults.

Objective: In this paper, we 1) described changes in older adult technology-based communication, technology-based phone use, and technology-based gaming during the COVID-19 pandemic, compared to before the COVID-19 pandemic and 2) tested whether technology use moderated the association between changes in in-person visits and well-being, controlling for covariates.

Methods: Between December 2020 and January 2021 we conducted a telephone-based objective survey with 60 previously hospitalized older New Yorkers with physical disability. We measured technology-based communication through three questions pulled from the National Health and Aging Trends Study COVID-19 Questionnaire. We measured technology-based smart phone use and technology-based video gaming through the Media Technology Usage and Attitudes Scale. We used paired t tests and interaction models to analyze survey data.

Results: This sample of previously hospitalized older adults with physical disability consisted of 60 participants, 63.3% of whom identified as female, 50.0% of whom identified as White, and 63.8% of whom reported an annual income of $25,000 or less. This sample had not had physical contact (such as friendly hug or kiss) for a median of 60 days and had not left their home for a median of 2 days. The majority of older adults from this study reported using the internet, owning smart phones, and nearly half learned a new technology during the pandemic. During the pandemic, this sample of older adults significantly increased their technology-based communication (mean difference=7.4, \(P=0.003\)), smart phone use (mean difference=2.9, \(P=0.016\)), and technology-based gaming (mean difference=5.2, \(P=0.030\)). However, this technology use during the pandemic did not moderate the association between changes in in-person visits and well-being, controlling for covariates.
Conclusions: These study findings suggest that previously hospitalized older adults with physical disability are open to using or learning technology, but that technology use might not be able to replace in-person social interactions. Future research might explore the specific components of in-person visits that are missing in virtual interactions, and if they could be replicated in the virtual environment, or through other means.

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KEYWORDS
older adults; technology; COVID-19; well-being; elderly population; technology use; physical disability; virtual health; social interaction; digital gaming; digital learning

Introduction
Beginning with New York City as the COVID-19 epicenter in the United States (March-May 2020) [1,2], the pandemic generated morbidity and mortality numbers that had been unseen for a century. By the end of 2020, the Centers for Disease Control and Statistics ranked COVID-19 as the third leading cause of death, second only to heart disease and cancer [3]. Older adults, especially those with multimorbidity or existing deconditioning, have shouldered a disproportionate burden of the illness and death caused by COVID-19 [4-10].

In response to the COVID-19 pandemic, the first major public health strategy for disease containment was physical distancing, defined as maintaining space from others who are not within one’s household [8,11,12]. People who were aged 70 years and older or perceived themselves at an increased health risk reported greater adherence to physical distancing during the pandemic [13]. Numerous research studies have documented the psychosocial impact of such physical distancing measures for older adults such as increased depression, increased anxiety, increased loneliness, and decreased well-being [14-18].

In an effort to buffer the effects of COVID-19 distancing restrictions, many people maintained active lifestyles and social communication with others through technology-based platforms [19,20]. Examples of technology that were used to maintain activity engagement or social connection during the pandemic include web-based communication such as “video chat,” smartphone use such as reading the news, and web-based gaming. Historically, older adults have used novel technology less than younger populations [21-25]. However, the COVID-19 pandemic increased the importance of technology for all Americans, including older adults [26]. Although a few studies have suggested that older adults might have increased their technology use during the COVID-19 pandemic, further research is needed to confirm these findings, especially among different populations, and using validated surveys [26-31]. In particular, research on changes in technology use among previously hospitalized community-dwelling older adults, especially those with physical disability, is needed because older adults with multimorbidity and hospital-associated deconditioning were a population greatly impacted by COVID-19 and related distancing measures [4-10]. Obtaining knowledge regarding previously hospitalized older adults’ technology use, before and during the pandemic, could inform the appropriateness of technology-based interventions for vulnerable older adults.

For the purposes of this study, well-being was defined as a combination of emotional experiences (both positive and negative) of a person, as well as their life satisfaction [32]. Prior to the pandemic, research evidence on the association of technology use and the well-being of older adults had been inconsistent. Some studies indicated that novel technologies could help support the well-being of the aging population through facilitating social connection and optimizing their daily activities (eg, information gathering and health maintenance) [33-36]. Alternatively, other studies have suggested that such conclusions are overgeneralizations based on scarce evidence and poor study methodology [37,38]. Although further research is needed to examine this association, researchers must consider that the simple association of technology use and well-being could offer misleading findings when using data from the pandemic [28]. For example, older adults who had more stress and anxiety related to the pandemic were more likely to decrease their in-person visits with family and friends, and older adults who were more likely to decrease their in-person visits with family and friends were more likely to use technologies to maintain that connection [28]. Thus, examining a cross-sectional association between technology use and well-being, while not taking into account pandemic-related changes in in-person visits, might overstate the negative effects of technology use on older adults. Instead, research is needed to examine if older adults’ technology use changed the relationship between fewer in-person visits and well-being. Obtaining knowledge regarding the role of technology in buffering the emotional impact of distancing restrictions for previously hospitalized community-dwelling older adults is important because such research can inform future interventions that increase their technology use and access [39].

This study had two aims: (1) to describe changes in older adults’ technology-based communication, technology-based phone use, and technology-based gaming during the COVID-19 pandemic, compared to before the COVID-19 pandemic, and (2) to test whether technology use moderated the association between changes in in-person visits and well-being, controlling for demographics such as age, gender, income, and living alone status. For this study, we applied Galappatti and Richardson’s [40] Well-being Conceptual Framework, which describes the linkage between well-being and disaster risk reduction. According to this framework, disaster events can deplete the resources that help a person maintain their well-being. Elements that bolster well-being during a disaster are (1) social ecological factors, which include maintaining relationships and venues for engagement, (2) human capacity, which includes maintaining skills, knowledge, and a sense of identity, and (3) the material
environment, which includes infrastructure and physical safety and comfort [40]. Consistent with this conceptual framework, older adults might have increased their technology use during the pandemic to maintain social ecological factors and human capacity. Additionally, those older adults who had high technology use during the COVID-19 pandemic, and thus bolstered their social ecological factors and human capacity, might have experienced higher well-being. Informed by Galappatti and Richardson’s [40] Well-being Conceptual Framework, we hypothesized that previously hospitalized older adults with physical disability increased their technology use during the pandemic, and that this technology use buffered the negative impact of decreased in-person visits on older adults’ well-being.

Methods

Sampling

CAPABLE (Community Aging in Place—Advancing Better Living for Elders) is a home-based intervention that addresses function through personalized goal-setting to improve the health and safety of older adults. We recruited participants from a research study based in New York City, conducted in collaboration with the Center for Home Care Policy & Research at VNS Health, testing whether CAPABLE decreases posthospitalization disability. Participants were eligible for the CAPABLE parent study if they were (1) aged 65 years or older, (2) within a 60-74-day period post hospital discharge, (3) discharged from postacute home health services, (4) able to stand up with or without assistance, (5) experiencing physical disability as determined by patient verbalization of difficulty with at least one activity of daily living (eg, difficulty walking or difficulty dressing), (6) not actively receiving radiation treatment or chemotherapy, (7) hospitalized 3 times or less in the last 12 months, (8) living in New York City for the next 5 months, and (9) cognitively intact, as determined by a score of ≥5 on the Callahan 6-item screenner [41]. Participants were eligible for this substudy if they (1) were participants in the CAPABLE parent study and (2) received a score of ≥5 on the Callahan 6-item screenner [41] at the time of the substudy’s interview survey. At the time of the substudy’s interview survey, participants were in a period between 13 and 28 months post hospitalization. In the order of participation in the CAPABLE parent study, we included the first 60 older adults who passed the cognitive screen and agreed to participate in this substudy.

Data Collection

We collected data between December 2020 and January 2021, which was shortly after the peak of the COVID-19 pandemic in New York City. Considering the physical distancing measures instituted during this period, and some older adults’ reticence with computer use, we used a telephone-based objective survey. The researchers who surveyed participants (BFD and JWL) were trained in proper techniques for conversing with those with hearing impairment (eg, talking slower not louder and rewording). The survey contained 50 items, most of which were multiple-choice questions, and took approximately 40 minutes to complete. We audio-recorded all calls, which the first author (BFD) checked for accuracy.

Ethical Considerations

The Johns Hopkins University’s institutional review board and VNS Health’s institutional review board approved this study (E17-002). Prior to participation, a research assistant (BFD or JWL) informed participants that the study participation was voluntary, and if they chose not to participate, their care at VNS Health would not be affected. All participants provided verbal informed consent and all participant data were deidentified. Participants were mailed a US $25 gift card for their study participation.

Survey Measures

Technology Use

Although data for this study were collected at one time point, we asked participants about their technology use currently, as well as (retrospectively) prior to the pandemic, which allowed for the examination of changes in older adults’ technology use during the pandemic. Similar to the National Health and Aging Trends Study COVID-19 Questionnaire [28,42], we established March 2020 as the time point in which “the effects of the outbreak first began.” For the 2 time frames “before the pandemic” and “during the pandemic,” we measured 3 types of technology: technology-based communication, technology-based smartphone use, and technology-based video gaming. These 3 measures of technology use are described below.

We measured technology-based communication through 3 questions extracted from the National Health and Aging Trends Study COVID-19 Questionnaire and described by Drazich et al [28] and Freedman Vicki and Kasper [42]. These items assess the frequency of social communication with family and friends through various forms of technology: (1) telephone calls, (2) emails, texts, and social media, and (3) video calls. For each item, participants reported their weekly frequency using a 5-point scale from 0=“never” to 4=“at least daily.” Summed responses ranged from 0 to 12, with higher scores indicating the highest frequency of technology-based communication. These 3 technology-based communication questions were asked in relation to the period “during the COVID-19 pandemic” and (retrospectively) “before the COVID-19 pandemic.”

We measured technology-based smartphone use through the 9-item “Smartphone Usage Sub-Scale” within the Media Technology Usage and Attitudes Scale [43]. The Smartphone Usage Sub-Scale has a Cronbach α of .93 [43]. These items assess how often a participant uses his/her smartphone for 9 purposes: reading emails, getting directions, browsing the web, listening to music, taking pictures, checking the news, recording a video, using apps, or searching for information. For each item, participants respond using a 10-point frequency scale from 1=“never” to 10=“all the time.” Summed responses ranged from 9 to 90 with higher scores indicating the highest frequency of smartphone use. These 9 technology-based smartphone questions were asked in relation to the time period “during the COVID-19 pandemic” and (retrospectively) “before the COVID-19 pandemic.” Of note, the Smartphone Usage Sub-Scale was only administered to participants who responded “yes” to owning a smartphone.
We measured technology-based video gaming through the 3-item “Video Gaming Sub-Scale” within the Media Technology Usage and Attitudes Scale [43]. The Video Gaming Sub-Scale has a Cronbach α of .83 [43]. These items assess how often a participant plays games on his/her computer, video game console, or smartphone (1) by him-/herself, (2) with other people in the same room, and (3) with other people on the web. Again, for each item, participants respond using a 10-point frequency scale from 1 “never” to 10 “all the time.” For the Video Gaming Sub-Scale, summed responses ranged from 3 to 30, with higher scores indicating the highest frequency of video gaming. These 3 technology-based video gaming questions were asked in relation to the period “during the COVID-19 pandemic” and (retrospectively) “before the COVID-19 pandemic.”

For descriptive purposes, we asked whether participants had access to the internet (yes/no), owned a smartphone (yes/no), and whether they learned a new technology during the COVID-19 pandemic (yes/no) and why (open answer).

Change in in-Person Visits

We measured change in in-person visits through a question that asked, “In a typical week, how often have you been in contact through in-person visits with family and friends not living with you?” Participants reported 0=“never,” 1=“less than once a week,” 2=“about once a week,” 3=“a few times a week,” or 4=“at least daily.” We asked this question for 2 periods: “before the pandemic” (retrospective report) and “during the pandemic.” We then subtracted responses “before the pandemic” from “during the pandemic” to obtain the “change in in-person visits” score. This “change in in-person visits” score ranged from −4 to +4, with negative numbers indicating a decrease in in-person visits during the pandemic and positive numbers indicating an increase in in-person visits during the pandemic. For descriptive purposes, we also asked the participants to report the number of days since they last had physical contact with a person (friendly hug or kiss), and the number of days since they had left their house for any reason (walk, grocery store, and pharmacy).

Well-being

We measured well-being through the 4-item Personal Well-being Scale [44]. The Personal Well-being Scale has an interitem correlation coefficient of 0.77 and Cronbach α of .9 [44]. These items assess both the emotional components (“I was happy yesterday” and “I was not anxious yesterday”) and the life satisfaction components (“I am satisfied with my life” and “What I do in my life is worthwhile”) of well-being [32,44]. Participants responded using a 4-point Likert scale from “disagree” to “strongly agree.” “I was not anxious yesterday” was reverse coded and all items were summed for a range between 0 and 16, with higher scores indicating better well-being.

Covariates

We included 4 covariate variables that are associated with older adult technology use and were collected through self-report: age, gender, living alone status, and income. We measured age on a raw continuous scale (see Table 1). Gender and living alone status consisted of 2 nominal categories (male/female; lives alone/lives with others). We measured income through interval data with six categories ranging from US $5000-$9999 annually to US $100,000 or above annually, with higher scores indicating greater income.

Statistical Analysis

We first conducted descriptive analyses for each variable, assessed measures of central tendency and outliers, as well as model assumptions. To fulfill the first study aim, which was to describe changes in technology use due to the COVID-19 pandemic, we performed paired t tests. To fulfill the second study aim, to test whether technology use significantly changed the relationship between changes in in-person visits and well-being, we tested an interaction model with technology use as the moderator. We considered a 1-sided P value of <.05 as statistical significance and performed statistical analyses using SPSS (version 26; IBM Corp).

Results

Sample

Our sample consisted of 60 participants, 63.3% of whom identified as female, and 50.0% of whom identified as White (see Table 1). The participants reported various chronic conditions, with a total of 14 (23.3%) reporting a history of heart attack, 24 (40%) reporting a history of asthma or wheezing, 16 (26.7%) reporting a history of colitis, and 13 (21.7%) reporting a history of cancer. The majority of participants (63.8%) had an annual income of US $25,000 or less and 46.7% of participants reported living alone. On a scale from 0–4, with 4 indicating the highest score for in-person visits, participants decreased their in-person visits from a score of 2.19 before the pandemic to a score of 1.49 during the pandemic (mean difference −70, P <.001). At the time of the survey between December 2020 and January 2021, participants reported that they had not had physical contact (such as friendly hug, kiss, or handshake) for a median of 60 days and had not left their home for a median of 2 days. A total of 10 (17%) participants in this sample reported that they had not left their home for more than 20 days. Approximately 54 (90%) participants reported having access to the internet and 40 (66.7%) participants reported owning a smartphone. A total of 28 (46.7%) participants reported “learning a new technology during the pandemic.” The most common type of technology learned was videoconferencing software for the purpose of socialization, health (eg, telehealth), or activity engagement (eg, religious service). The average well-being score, which ranges 0–16 with higher scores indicating higher well-being, was 11.03 (SD 3.4).
Table 1. Participant characteristics (N=60).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (SD)</td>
<td>75.9 (7.1)</td>
</tr>
<tr>
<td>Age (years), n (%)</td>
<td></td>
</tr>
<tr>
<td>65-69</td>
<td>12 (20)</td>
</tr>
<tr>
<td>70-74</td>
<td>16 (27)</td>
</tr>
<tr>
<td>75-79</td>
<td>12 (20)</td>
</tr>
<tr>
<td>80-84</td>
<td>15 (25)</td>
</tr>
<tr>
<td>85-89</td>
<td>4 (7)</td>
</tr>
<tr>
<td>90+</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>38 (63)</td>
</tr>
<tr>
<td>Men</td>
<td>22 (37)</td>
</tr>
<tr>
<td>Race or ethnicity, n (%)</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>30 (50)</td>
</tr>
<tr>
<td>African American</td>
<td>21 (35)</td>
</tr>
<tr>
<td>Other</td>
<td>9 (15)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>8 (14)</td>
</tr>
<tr>
<td>Incomea (US $), n (%)</td>
<td></td>
</tr>
<tr>
<td>5000-9999</td>
<td>10 (17)</td>
</tr>
<tr>
<td>10,000-14,999</td>
<td>11 (19)</td>
</tr>
<tr>
<td>15,000-24,999</td>
<td>16 (28)</td>
</tr>
<tr>
<td>25,000-34,999</td>
<td>7 (12)</td>
</tr>
<tr>
<td>≥35,000</td>
<td>14 (24)</td>
</tr>
<tr>
<td>Live alone status, n (%)</td>
<td></td>
</tr>
<tr>
<td>Live alone</td>
<td>28 (47)</td>
</tr>
<tr>
<td>Live with others</td>
<td>32 (53)</td>
</tr>
<tr>
<td>Educationa, n (%)</td>
<td></td>
</tr>
<tr>
<td>More than high school</td>
<td>6 (10)</td>
</tr>
<tr>
<td>High school</td>
<td>19 (33)</td>
</tr>
<tr>
<td>Technical degree</td>
<td>5 (9)</td>
</tr>
<tr>
<td>Associate’s or bachelor’s degree</td>
<td>16 (28)</td>
</tr>
<tr>
<td>Graduate school</td>
<td>12 (21)</td>
</tr>
</tbody>
</table>

A total of 2 participants refused to report their income and educational attainment.

Aim 1: Change in Technology Use

Fulfilling aim 1, we first tested if older adults’ technology-based communication, technology-based smartphone use, and technology-based gaming increased during the COVID-19 pandemic, compared to before the COVID-19 pandemic. We found that our sample of 60 previously hospitalized older adults with physical disability significantly increased their technology-based communication (P=.003), smartphone use (P=.02), and technology-based gaming (P=.03) during the pandemic, compared to those before the pandemic (see Table 2). On a scale from 0 to 12, with higher scores indicating the highest frequency of technology-based communication, older adults increased their technology-based communication from 6.4 points to 7.1 points. In particular, older adults who responded “never” to frequency of video calls changed from 63.3% before the pandemic, to 44.1% during the pandemic. On a scale from 9 to 90, with higher scores indicating the highest frequency of smartphone use, older adults increased their smartphone use from 27.0 points to 30.0 points. On a scale from 3 to 30, with higher scores indicating the highest frequency of technology-based gaming, older adults increased their technology-based gaming from 5.2 points to 5.7 points.
This sample of 60 previously hospitalized older adults with physical disability significantly increased their technology-based communication, smartphone use, and technology-based gaming during the pandemic, compared to before the pandemic. This finding complements previous research, which indicated that older adults increased their technology use during the pandemic [27,28,45]. This finding is distinct from previous findings in that it specifically examined smartphone use and web-based gaming using surveys with tested psychometric properties, and was in a sample of vulnerable older adults [43]. This study also found that technology use during the pandemic did not significantly moderate the association between changes in in-person visits and well-being. Thus, the relationship between change in in-person visits and well-being is the same, regardless of level of technology use.

Discussion

Principal Findings

This study was guided by Galappatti and Richardson’s [40] Well-being Conceptual Framework, which suggests that the following elements bolster well-being during a disaster: (1) social ecological factors, (2) human capacity, and (3) the material environment. Consistent with this framework, we hypothesized that older adults who had high technology use during the COVID-19 pandemic, and thus bolstered their social ecological factors and human capacity, would have higher associated well-being. The framework’s third element that contributes to well-being, the “material environment,” was not explored in this study, but might help explain our finding that technology use did not buffer the effects of changes in in-person visits on older adults’ well-being. The “material environment” includes infrastructure and the degree of physical safety and comfort. In this study, older adults who used technology could have had financial concerns related to data usage, internet security concerns, stress due to technology use confusion, or addictive technology tendencies. Greater research is needed to investigate the potential negative effects of technology on older adults such as problematic technology use and technostress [46,47].

The findings that technology use did not significantly buffer the effects of changes in in-person visits on older adults’ well-being was a surprising finding and can have implications far beyond the pandemic. Older adults are often unable to experience in-person interaction due to a variety of reasons, such as mobility limitations, transportation inaccessibility, or income restraints. This study indicates that technology might not provide or supplement the full benefits of in-person visits. Future research might explore the specific components of in-person visits that are missing in digital interactions, and if they could be replicated in the digital environment, or through other means. In particular, greater investment in social or “cuddly” robotics might be warranted in the field of geriatrics, especially robots with high usability and safety, and those that are designed to support the values of the individual users [48-51].

Limitations

Given the small sample size of 60 participants, this study might not have been powered to find statistical differences. Additionally, this sample was drawn from a population of older adults who live in New York City and had already received the CAPABLE intervention, which addresses physical function through goal-setting. Thus, this sample might be different form the general population of recently hospitalized older adults with functional disability who have not received the CAPABLE intervention or who live in different geographic regions. Another study limitation was the data collection at one time point. Participants might have had difficulty retrospectively reporting on their technology use prior to the COVID-19 pandemic (recall bias). Conversely, a strength of this study was the inclusion of older adults who are underrepresented in geriatric research, such as non-technology users [21-25]. The majority of previously hospitalized older adults from this study reported using the internet and owning smartphones, and nearly half of them learned a new technology during the pandemic. Thus, researchers should consider that many older adults are open to using technology, and this should, therefore, be considered in the design and implementation of technology-based health interventions. Second, the finding that nearly half of this sample of previously hospitalized older adults with physical disability learned a new technology during the pandemic indicates that many vulnerable older adults might be open to learning new technology-based interventions.
as adults older than 75 years, Black older adults, and low-income older adults.

Conclusions
This study found that previously hospitalized older adults significantly increased their technology use during the pandemic, compared to before the pandemic, but this technology use did not significantly moderate the association between changes in in-person visits and well-being. These study findings suggest that older adults are open to using or learning technology, but that technology use might not be able to replace in-person social interactions. These findings can guide researchers and clinicians in the postpandemic environment for the planning of technology-based health interventions.

Acknowledgments
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Data Availability
The data sets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest
None declared.

References


Chopik WJ. The benefits of social technology use among older adults are mediated by reduced loneliness. Cyberpsychol Behav Soc Netw 2016 Sep;19(9):551-556 [FREE Full text] [doi: 10.1089/cyber.2016.0151] [Medline: 27541746]


Abbreviations
CAPABLE: Community Aging in Place–Advancing Better Living for Elders

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COVID-19 Infodemic and Impacts on the Mental Health of Older People: Cross-sectional Multicenter Survey Study

Patricia Rodrigues Braz¹, BSc, MSc; Tiago Ricardo Moreira², BSc, MSc, PhD; Andréia Queiroz Ribeiro², BSc, MSc, PhD; Luciane Ribeiro de Faria³, BSc, MSc, PhD; Fabio da Costa Carbogim¹,², BSc, MSc, PhD; Vilanime Alves de Araujo Puschel¹, BSc, MSc, PhD; Jack Roberto Silva Fon³, BSc, MSc, PhD; Eduarda Rezende Freitas⁵, BSc, MSc, PhD; Ione Carvalho Pinto⁶, BSc, MSc, PhD; Fabiana Costa Machado Zacharias⁶, BSc, MSc, PhD; Gylce Eloisa Cabreira Panitz Cruz⁷, BSc, MSc, PhD; Richardson Miranda Machado⁷, BSc, MSc, PhD; Rosimere Ferreira Santana⁸, BSc, MSc, PhD; Priscilla Alfradique de Souza⁹, BSc, MSc, PhD; Grazielle Ribeiro Bitencourt¹⁰, BSc, MSc, PhD; Alexandre Favero Bulgarelli¹¹, BSc, MSc, PhD; Ricardo Bezerra Cavalcante³, BSc, MSc, PhD

¹Universidade Federal de Juiz de Fora, Juiz de Fora, Brazil
²Universidade Federal de Viçosa, Viçosa, Brazil
³Universidade Federal de Juiz de Fora - MG, Brazil
⁴Universidade de São Paulo, São Paulo, Brazil
⁵Universidade Católica de Brasília, Brasília, Brazil
⁶Universidade de São Paulo, Ribeirão Preto, Brazil
⁷Universidade Federal de São João Del Rei, Divinópolis, Brazil
⁸Universidade Federal Fluminense, Niterói, Brazil
⁹Universidade Federal do Estado do Rio de Janeiro, Rio de Janeiro, Brazil
¹⁰Universidade Federal do Rio de Janeiro, Macaé, Brazil
¹¹Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

Corresponding Author:
Ricardo Bezerra Cavalcante, BSc, MSc, PhD
Universidade Federal de Juiz de Fora
Campus Universitário
Rua José Lourenço Kelmer, s/n - São Pedro
Juiz de Fora - MG, 36036-900
Brazil
Phone: 55 32 85033443
Email: ricardo.cavalcante@ufjf.br

Abstract

Background: The COVID-19 pandemic received widespread media coverage due to its novelty, an early lack of data, and the rapid rise in deaths and cases. This excessive coverage created a secondary “infodemic” that was considered to be a serious public and mental health problem by the World Health Organization and the international scientific community. The infodemic particularly affected older individuals, specifically those who are vulnerable to misinformation due to political positions, low interpretive and critical analysis capacity, and limited technical-scientific knowledge. Thus, it is important to understand older people’s reaction to COVID-19 information disseminated by the media and the effect on their lives and mental health.

Objective: We aimed to describe the profile of exposure to COVID-19 information among older Brazilian individuals and the impact on their mental health, perceived stress, and the presence of generalized anxiety disorder (GAD).

Methods: This cross-sectional, exploratory study surveyed 3307 older Brazilians via the web, social networks, and email between July 2020 and March 2021. Descriptive analysis and bivariate analysis were performed to estimate associations of interest.

Results: Major proportions of the 3307 participants were aged 60 to 64 years (n=1285, 38.9%), female (n=2250, 68.4%), and married (n=1835, 55.5%) and self-identified as White (n=2364, 71.5%). Only 295 (8.9%) had never started or completed a basic education. COVID-19 information was mainly accessed on television (n=2680, 81.1%) and social networks (n=1943, 58.8%). Television exposure was ≥3 hours in 1301 (39.3%) participants, social network use was 2 to 5 hours in 1084 (32.8%) participants, and radio exposure was ≥1 hour in 1223 (37%) participants. Frequency of exposure to social networks was significantly associated
with perceived stress (P=.04) and GAD (P=.01). A Bonferroni post hoc test revealed significantly different perceived stress in participants who were exposed to social networks for 1 hour (P=.04) and those who had no exposure (P=.04). A crude linear regression showed that “some” social media use (P=.02) and 1 hour of exposure to social media (P<.001) were associated with perceived stress. Adjusting for sociodemographic variables revealed no associations with this outcome variable. In a crude logistic regression, some social media use (P<.001) and 2 to 5 hours of exposure to social media (P=.03) were associated with GAD. Adjusting for the indicated variables showed that some social network use (P<.001) and 1 hour (P=.04) and 2 to 5 hours (P=.03) of exposure to social media were associated with GAD.

Conclusions: Older people, especially women, were often exposed to COVID-19–related information through television and social networks; this affected their mental health, specifically GAD and stress. Thus, the impact of the infodemic should be considered during anamnesis for older people, so that they can share their feelings about it and receive appropriate psychosocial care.

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KEYWORDS

information dissemination; health communication; COVID-19; COVID-19 pandemic; public health; health of older people; mental health

Introduction

The COVID-19 pandemic has been described as the greatest health crisis of the 21st century and is recognized as a public health emergency of international importance [1,2]. COVID-19 is a highly contagious infectious disease. Its main symptoms are coughing, sore throat, runny nose and nasal congestion, fatigue, anosmia, ageusia, diarrhea, headache, and skin rashes. Other symptoms are more severe, such as severe acute respiratory syndrome, shock, and multiple organ dysfunction. In Brazil, the disease caused more than 700,000 deaths [3].

Due to the novelty of the diagnosis, the initial lack of information, and the rapid dissemination of the disease worldwide, as well as the number of deaths and symptomatic cases, the COVID-19 pandemic quickly received wide media coverage. Excessive information related to the disease caused problems secondary to the pandemic, constituting an “infodemic” that impacted the lives of individuals. The World Health Organization and the scientific communities of different countries consider infodemics a serious public health problem [4].

Infodemics are defined by the volume of information associated with a specific subject multiplying quickly in a short time [4]. In this context, Wardle and Derakshan [5] described different terms related to the disclosure of information, constituting what the authors call “an ecosystem of disinformation.”

This ecosystem is composed of 3 large groups: “misinformation,” “malinformation,” and “disinformation.” Misinformation refers to false information disseminated without the primary intention of causing harm. Malinformation is based on legitimate content but is used to cause harm; information is taken out of context or manipulated to achieve the goal of causing harm [5]. By contrast, disinformation is the creation of false information designed specifically for a harmful purpose [5,6].

In Brazil, the political context added to the COVID-19 infodemic and led to the emergence of conspiracy theories and misinterpretations of data and scientific research that were grounded in denialism, which requires the acceptance of interventions without scientific validation. Denialist perspectives on COVID-19 are at the heart of antiscientific and even antihistorical thinking, with the rhetoric of the antivaccine movement being an example. This discourse is characterized by being cyclical and permeated by ethical-political and ideological issues, in which actions are intentional [7,8].

Among all age groups, the infodemic has had the greatest impact on the lives of older individuals. In addition to their political positions and behavior, older people who have low interpretive and critical analysis capacity and limited technical-scientific knowledge tend to generate more misinformation and be exposed to more misinformation, which can impact their mental health. Older individuals represent the largest proportion of functionally illiterate individuals in Brazil, and the illiteracy rate in people aged 60 years or older reaches 10.3% among White people, increasing to 27.5% among other racial groups; moreover, 53% of people aged between 50 and 64 years are considered functionally illiterate, which makes them vulnerable to being targets of misinformation, as well as being its main propagators [9].

Older people are not digital natives but are increasingly active and, consequently, are gradually starting to use computerized media and gain access to other media. Internet use has grown most rapidly among older people over the years, increasing by 56% between 2015 and 2017 [10] and by 97% by 2021 [11].

Given the above, it is important to understand how older people react to information about COVID-19 disseminated by the media, what effects this information has on their lives, and how it can affect their mental health. Thus, we conducted this study, which is derived from an international multicenter study titled “COVID-19 infodemic and its repercussions on the mental health of the elderly during and postpandemic: A multicenter study Brazil/Chile/Peru/Colombia/Mexico and Portugal.” We aimed to describe the profile of exposure to information on COVID-19 among older Brazilian individuals and determine the mental health repercussions of this exposure by screening for perceived stress and generalized anxiety disorder (GAD). The following hypothesis guided the collection and analysis of quantitative data: There are associations between variables
related to the COVID-19 infodemic, GAD, and perceived stress among older Brazilian people.

With regard to screening for perceived stress and GAD, it is necessary to understand aspects of these conditions that are accentuated in the context of an infodemic and pandemic.

Stress has multiple etiologies and can be understood as the result of exposure to events considered stressful that exceed the body’s ability to control or manage them; this generates important behavioral symptoms, such as fear, avoidance behaviors, irritability, and repetitive nightmares. Stress is also a symptom of several mental disorders [12].

The diagnosis of GAD is based on excessive anxiety, worry, and apprehensive anticipation that occur on most days for at least 6 months and are related to a variety of events or activities that the individual finds it difficult to control. Anxiety and worry are generally associated with signs and symptoms of restlessness, fatigability, difficulty concentrating, irritability, muscle tension, and sleep disturbance; these signs and symptoms persist and cause clinically significant distress or impairment in social and professional functioning [12].

Methods

Overview

This paper is derived from an international multicenter study that is still ongoing, titled “COVID-19 infodemic and its repercussions on the mental health of the elderly during and postponemic: A multicenter study Brazil/Chile/Peru/Colombia/Mexico and Portugal,” which seeks to analyze the COVID-19 infodemic and its repercussions on the mental health of older individuals.

This is a cross-sectional, quantitative, exploratory study conducted among people aged 60 years or older in several Brazilian municipalities. Participants eligible for this study were older Brazilians who had access to the internet and social networks.

The data collection instruments were delivered through a web-based survey between July 2020 and March 2021. The access link was sent by email and through social networks; up to 3 attempts were made over 3 months. Mediation with older people was performed in collaboration with scientific societies for geriatrics and gerontology, health care units, and associations of retirees; direct contact was also made with older people who were already being monitored through research and outreach activities at the collaborating research centers.

When they first accessed the link, the participants were directed to a digital informed consent form where they either accepted or refused to participate in the study. The choice to participate or not participate in the study was automatically recorded in a database generated by the web-based survey. Those who chose to continue participating in the study gained access to the research questions.

The data collection instrument was adapted from studies by Ahmad and Murad [13] and Gao et al [14] and measured demographic and socioeconomic variables. In addition, it included variables related to the COVID-19 infodemic that measured types of media accessed, including social networks, radio, and television, and the time of exposure to these media as frequency and hours. The Perceived Stress Scale (PSS) was used to screen for perceived stress and was analyzed as a continuous variable [15]. The Geriatric Anxiety Inventory (GAI) was used to screen for GAD and was analyzed according to studies validated and conducted in Brazil; a cutoff score of 13 indicated the presence of GAD [16].

The final version of the database was transferred from Microsoft Excel (Microsoft Corp) to SPSS (version 23.0; IBM Corp). The treatment and descriptive analysis procedures were performed through sociodemographic characterization of the participants and with reference to variables related to exposure to COVID-19–related news and information in the media. For the qualitative variables, the absolute and relative frequencies were estimated. For the quantitative variables, measures of position (mean and median) and dispersion (SD, IQR, and minimum and maximum) were estimated according to data distribution (symmetric or asymmetric).

Responses to the PSS questionnaire were analyzed by calculating position and dispersion measures. The estimated prevalence of GAD among the population was determined according to a cutoff point adopted for the analysis of the GAI.

A 1-way analysis of variance (ANOVA) was used to determine differences in mean perceived stress in the participants based on infodemic exposure and sociodemographic characteristics using the Bonferroni post hoc test and a significance level of P<.05. Multiple linear regression analysis was performed to estimate the crude and adjusted regression coefficients with 95% CIs for the association between the independent variables of interest and the perceived stress outcome.

The associations between infodemic variables and outcomes related to the geriatric anxiety screening were assessed using the chi-square test. Subsequently, crude and adjusted multiple logistic regression analyses were performed to identify associations between the independent variables of interest and the GAD outcome with the 95% CI. The significance level adopted in all tests was 5%.

Ethical Considerations

The study was approved by the Brazilian National Research Ethics Committee (Comissão Nacional de Ética em Pesquisa) on March 7, 2020 (CAAE 31932620.1.1001.5147; opinion 4.134.050). Data collection was initiated after approval.

This study complied with all ethical and legal requirements specific to investigations involving human beings, in line with the regulatory provisions of Brazilian Resolution No 466/12 of the National Health Council. The interviewees were guaranteed anonymity and codenames were used to represent them in the study. The participants were informed about the study’s objectives, its justification, and the research procedures, and it was explained to them that participation was voluntary, without financial advantages or expenses. Findings will be disclosed only at scientific events or in journals.

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The data and instruments used in the research will be archived with the responsible researcher for a period of 5 years and will be destroyed after that period. Authorizations were requested from the institutions involved to carry out the research. The consent to said documents relies on the performance of the study, description of the methods, and the dissemination of results exclusively in events or journals of a scientific nature.

**Results**

A total of 3307 older individuals participated in the study, of whom 2250 (68.4%) were female, 1285 (38.9%) were aged between 60 and 64 years, 1835 (55.5%) were married, and 2364 (71.5%) were White. Housing data showed that 3160 (95.6%) lived in an urban area and 1886 (57%) lived in homes with 1 or 2 people. Only 295 (8.9%) had not started or completed basic education, while 645 (19.5%) had completed higher education. The majority, 1343 (40.6%), used free and paid health services. In addition, 2437 (73.8%) responded that the pandemic did not affect their monthly income (Table 1).

The most used resources to access news and information about COVID-19 during the day among the 3307 participants were television, used by 2680 (81.1%), and social networks, used by 1943 (58.8%); only 876 (26.5%) used the radio. Participants also self-reported their frequency of exposure to information and news about COVID-19 over a period of 1 week (ie, 7 days), ranging from “no exposure” to “frequent exposure.” Television was reported as a frequent source by 1473 (44.5%) participants, while social networks were reported as sometimes being a source by 1464 (44.3%) patients. In contrast, the radio was not a source of exposure for the majority of participants (n=1956, 59.1%). Television exposure was 3 hours or more for 1301 (39.3%) participants, social network exposure was 2 to 5 hours for 1084 (32.8%) participants, and radio exposure was 1 hour or more for 1223 (37%) participants (Table 2).

An ANOVA testing the association of perceived stress with infodemic variables showed a significant association between perceived stress and frequency of exposure to social networks (P=.04). It is also noteworthy that the mean score for perceived stress was higher (mean 20.84, SD 9.55) among those who had no exposure to social networks. The Bonferroni post hoc test revealed that the perceived stress of participants who were exposed to social networks for 1 hour (P=.04) and those who had no exposure to social networks (P=.04) differed significantly. There was also a significant association with hours of exposure to news and information about COVID-19 on social networks (P=.02; Table 3).

Approximately 143 of 822 (17.4%) of participants who were not exposed to social networks and 173 of 1021 (16.9%) who were frequently exposed to social networks had a GAI score that indicated GAD (P<.001). A significant association was found between geriatric anxiety and hours of exposure to news and information about COVID-19 on social networks (P=.01). Among the participants, 73 of 395 (18.5%) who were frequently exposed to radio as a means of information and 105 of 560 (18.8%) who were exposed to social networks for 6 hours or more had a GAI score that indicated GAD (Table 4).

Logistic regression analyses were performed a GAI score indicating GAD as the outcome variable, and linear regression was used for perceived stress to estimate the raw and adjusted regression coefficients for the predictor variables (ie, the sociodemographic variables: age group, gender, education, cohabitation status, and income changes) and the infodemic variables.

The crude linear regression showed that some frequency of exposure to social networks (P=.02) and 1 hour of exposure to social networks (P<.001) were associated with perceived stress. In the analysis adjusted for the sociodemographic variables, no associations were found with the outcome variable. In the crude logistic regression, some frequency of exposure to social networks (P<.001) and 2 to 5 hours of exposure to social networks (P=.03) were also associated with GAD. In the adjusted analysis for the indicated variables, some frequency of exposure to social networks (P<.001), 1 hour of exposure to social networks (P=.04), and 2 to 5 hours of exposure to social networks (P=.03) were associated with a GAI score indicating GAD (Table 5).
Table 1. Sociodemographic profile of participants in this study (n=3307).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Participants, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2250 (68.4)</td>
</tr>
<tr>
<td>Male</td>
<td>1039 (31.6)</td>
</tr>
<tr>
<td>Prefer not to declare</td>
<td>18 (0.5)</td>
</tr>
<tr>
<td><strong>City</strong></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>544 (16.4)</td>
</tr>
<tr>
<td>Juiz de Fora, Minas Gerais</td>
<td>470 (14.2)</td>
</tr>
<tr>
<td>São Paulo, São Paulo</td>
<td>412 (12.5)</td>
</tr>
<tr>
<td>Porto Alegre, Rio Grande do Sul</td>
<td>397 (12)</td>
</tr>
<tr>
<td>Divinópolis, Minas Gerais</td>
<td>381 (11.5)</td>
</tr>
<tr>
<td>Rio de Janeiro, Rio de Janeiro</td>
<td>352 (10.6)</td>
</tr>
<tr>
<td>Viçosa, Minas Gerais</td>
<td>335 (10.1)</td>
</tr>
<tr>
<td>Ribeirão Preto, São Paulo</td>
<td>251 (7.5)</td>
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<td>Brasília, Distrito Federal</td>
<td>165 (5)</td>
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<td><strong>Age group (years)</strong></td>
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<tr>
<td>60 to 64</td>
<td>1285 (38.9)</td>
</tr>
<tr>
<td>65 to 69</td>
<td>921 (27.9)</td>
</tr>
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<td>70 to 74</td>
<td>503 (15.2)</td>
</tr>
<tr>
<td>75 to 79</td>
<td>334 (10.1)</td>
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<td>80 or older</td>
<td>264 (8)</td>
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<td><strong>Marital status</strong></td>
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<td>Widowed</td>
<td>598 (18.1)</td>
</tr>
<tr>
<td>Separated</td>
<td>509 (15.4)</td>
</tr>
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<td>Single</td>
<td>365 (11)</td>
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<td><strong>Race</strong></td>
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<tr>
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<td><strong>Cohabitation</strong></td>
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<tr>
<td>Living alone</td>
<td>587 (17.8)</td>
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<tr>
<td>Living with 1 or 2 people</td>
<td>1886 (57)</td>
</tr>
<tr>
<td>Living with 3 or more people</td>
<td>834 (25.2)</td>
</tr>
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<td><strong>Own residence</strong></td>
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<td>551 (16.7)</td>
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<td><strong>Area of residence</strong></td>
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<td>Urban</td>
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<td>Rural</td>
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<td><strong>Maximum education</strong></td>
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<td>Did not complete basic education</td>
<td>295 (8.9)</td>
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<td>Basic or elementary education</td>
<td>713 (21.6)</td>
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<td>Secondary education</td>
<td>718 (21.7)</td>
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<td>Variables</td>
<td>Participants, n (%)</td>
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<tr>
<td>-----------------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Completed higher education</td>
<td>645 (19.5)</td>
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<tr>
<td>Specialization</td>
<td>512 (15.5)</td>
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<td>Master’s, doctoral, or postdoctoral degree</td>
<td>424 (12.8)</td>
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<tr>
<td><strong>Health services used</strong></td>
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<tr>
<td>Only paid health services (including health insurance)</td>
<td>1133 (34.3)</td>
</tr>
<tr>
<td>Both (free and paid)</td>
<td>1343 (40.6)</td>
</tr>
<tr>
<td>Only free health services</td>
<td>814 (24.6)</td>
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<tr>
<td>None</td>
<td>17 (0.5)</td>
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<td><strong>Receives retirement or pension income</strong></td>
<td></td>
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<tr>
<td>Yes</td>
<td>2565 (77.6)</td>
</tr>
<tr>
<td>No</td>
<td>740 (22.4)</td>
</tr>
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<td><strong>Pandemic altered income</strong></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>2437 (73.8)</td>
</tr>
<tr>
<td>Yes, my income decreased</td>
<td>787 (23.8)</td>
</tr>
<tr>
<td>Yes, my income increased</td>
<td>80 (2.4)</td>
</tr>
</tbody>
</table>
Table 2. Characteristics of the methods most commonly used to access news and information about COVID-19 and the frequency and hours of exposure (n=3307).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Participants, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Social network exposure (n=3303)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1943 (58.8)</td>
</tr>
<tr>
<td>No</td>
<td>1361 (41.2)</td>
</tr>
<tr>
<td><strong>Frequency of exposure</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>822 (24.9)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>1464 (44.3)</td>
</tr>
<tr>
<td>Often</td>
<td>1021 (30.9)</td>
</tr>
<tr>
<td><strong>Hours of exposure to news and information about COVID-19 on social networks</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>848 (25.6)</td>
</tr>
<tr>
<td>1</td>
<td>811 (24.5)</td>
</tr>
<tr>
<td>2 to 5</td>
<td>1084 (32.8)</td>
</tr>
<tr>
<td>6 or more</td>
<td>560 (16.9)</td>
</tr>
<tr>
<td><strong>Television exposure (n=3304)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2680 (81.1)</td>
</tr>
<tr>
<td>No</td>
<td>624 (18.9)</td>
</tr>
<tr>
<td><strong>Frequency of exposure</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>394 (11.9)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>1440 (43.5)</td>
</tr>
<tr>
<td>Often</td>
<td>1473 (44.5)</td>
</tr>
<tr>
<td><strong>Hours of exposure to news and information about COVID-19 on television</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>431 (13)</td>
</tr>
<tr>
<td>1</td>
<td>884 (26.7)</td>
</tr>
<tr>
<td>2</td>
<td>685 (20.7)</td>
</tr>
<tr>
<td>3 or more</td>
<td>1301 (39.3)</td>
</tr>
<tr>
<td><strong>Radio exposure (n=3304)</strong></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>876 (26.5)</td>
</tr>
<tr>
<td>No</td>
<td>2429 (73.5)</td>
</tr>
<tr>
<td><strong>Frequency of exposure</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1956 (59.1)</td>
</tr>
<tr>
<td>Sometimes</td>
<td>956 (28.9)</td>
</tr>
<tr>
<td>Often</td>
<td>395 (11.9)</td>
</tr>
<tr>
<td><strong>Hours of exposure to news and information about COVID-19 on the radio</strong></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2083 (63)</td>
</tr>
<tr>
<td>1 or more</td>
<td>1223 (37)</td>
</tr>
</tbody>
</table>
Table 3. Differences in mean Perceived Stress Scale score and infodemic variables (n=3307).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Perceived Stress Scale score, mean (SD)</th>
<th>$P$ value$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of exposure to social networks</td>
<td></td>
<td>.04</td>
</tr>
<tr>
<td>None</td>
<td>20.84 (9.55)</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>19.89 (9.27)</td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>20.61 (9.82)</td>
<td></td>
</tr>
<tr>
<td>Frequency of exposure to television</td>
<td></td>
<td>.33</td>
</tr>
<tr>
<td>None</td>
<td>20.03 (9.51)</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>20.16 (9.38)</td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>20.62 (9.65)</td>
<td></td>
</tr>
<tr>
<td>Frequency of exposure to radio</td>
<td></td>
<td>.89</td>
</tr>
<tr>
<td>None</td>
<td>20.36 (9.57)</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>20.40 (9.33)</td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>20.13 (9.72)</td>
<td></td>
</tr>
<tr>
<td>Hours of exposure to news and information about COVID-19 on social networks</td>
<td></td>
<td>.02</td>
</tr>
<tr>
<td>None</td>
<td>20.92 (9.46)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>19.68 (9.53)</td>
<td></td>
</tr>
<tr>
<td>2 to 5</td>
<td>20.11 (9.41)</td>
<td></td>
</tr>
<tr>
<td>6 or more</td>
<td>20.91 (9.77)</td>
<td></td>
</tr>
<tr>
<td>Hours of exposure to news and information about COVID-19 on television</td>
<td></td>
<td>.6</td>
</tr>
<tr>
<td>None</td>
<td>20.05 (9.67)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>20.07 (9.42)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20.50 (9.84)</td>
<td></td>
</tr>
<tr>
<td>3 or more</td>
<td>20.54 (9.38)</td>
<td></td>
</tr>
<tr>
<td>Hours of exposure to news and information about COVID-19 on the radio</td>
<td></td>
<td>.60</td>
</tr>
<tr>
<td>None</td>
<td>20.28 (9.53)</td>
<td></td>
</tr>
<tr>
<td>1 or more</td>
<td>20.46 (9.50)</td>
<td></td>
</tr>
</tbody>
</table>

$^a$One-way ANOVA between groups with Bonferroni correction and a significance level of $P<.05$. 
Table 4. Association between infodemic variables and screening for geriatric anxiety (n=3307).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Presence of geriatric anxiety (participants), n (%)</th>
<th>( P ) value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Frequency of exposure to social networks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (n=822)</td>
<td>143</td>
<td>679 (82.6)</td>
</tr>
<tr>
<td>Sometimes (n=1464)</td>
<td>194</td>
<td>1270 (86.7)</td>
</tr>
<tr>
<td>Often (n=1021)</td>
<td>173</td>
<td>848 (83.1)</td>
</tr>
<tr>
<td><strong>Frequency of exposure to television</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (n=394)</td>
<td>66</td>
<td>328 (83.2)</td>
</tr>
<tr>
<td>Sometimes (n=1440)</td>
<td>202</td>
<td>1238 (86)</td>
</tr>
<tr>
<td>Often (n=1473)</td>
<td>242</td>
<td>1231 (83.6)</td>
</tr>
<tr>
<td><strong>Frequency of exposure to radio</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (n=1956)</td>
<td>302</td>
<td>1654 (84.6)</td>
</tr>
<tr>
<td>Sometimes (n=956)</td>
<td>135</td>
<td>821 (85.9)</td>
</tr>
<tr>
<td>Often (n=395)</td>
<td>73</td>
<td>322 (81.5)</td>
</tr>
<tr>
<td><strong>Hours of exposure to news and information about COVID-19 on social networks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (n=848)</td>
<td>145</td>
<td>703 (82.9)</td>
</tr>
<tr>
<td>1 (n=811)</td>
<td>112</td>
<td>699 (86.2)</td>
</tr>
<tr>
<td>2 to 5 (n=1084)</td>
<td>148</td>
<td>936 (86.3)</td>
</tr>
<tr>
<td>6 or more (n=560)</td>
<td>105</td>
<td>455 (81.2)</td>
</tr>
<tr>
<td><strong>Hours of exposure to news and information about COVID-19 on television</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (n=431)</td>
<td>69</td>
<td>362 (84)</td>
</tr>
<tr>
<td>1 (n=884)</td>
<td>127</td>
<td>757 (85.6)</td>
</tr>
<tr>
<td>2 (n=685)</td>
<td>102</td>
<td>583 (85.1)</td>
</tr>
<tr>
<td>3 or more (n=1301)</td>
<td>212</td>
<td>1089 (83.7)</td>
</tr>
<tr>
<td><strong>Hours of exposure to news and information about COVID-19 on the radio</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None (n=2083)</td>
<td>306</td>
<td>1777 (85.3)</td>
</tr>
<tr>
<td>1 or more (n=1223)</td>
<td>204</td>
<td>1019 (83.3)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Chi-square test.
Table 5. Crude and adjusted logistic regression models for the Geriatric Anxiety Inventory score and crude and adjusted linear regression models for the Perceived Stress Scale score (n=3307).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Geriatric anxiety (logistic regression), ORa (95% CI)</th>
<th>Perceived stress (linear regression), OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude analysis</td>
<td>Adjusted analysisb</td>
</tr>
<tr>
<td>Frequency of exposure to social networks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sometimes</td>
<td>0.72 (0.57 to 0.91)</td>
<td>0.69 (0.53 to 0.90)</td>
</tr>
<tr>
<td>Often</td>
<td>0.96 (0.75 to 1.23)</td>
<td>0.92 (0.70 to 1.22)</td>
</tr>
<tr>
<td>Frequency of exposure to television</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sometimes</td>
<td>0.81 (0.59 to 1.09)</td>
<td>0.81 (0.59 to 1.10)</td>
</tr>
<tr>
<td>Often</td>
<td>0.97 (0.72 to 1.31)</td>
<td>0.97 (0.72 to 1.31)</td>
</tr>
<tr>
<td>Frequency of exposure to radio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sometimes</td>
<td>0.90 (0.72 to 1.12)</td>
<td>0.88 (0.71 to 1.11)</td>
</tr>
<tr>
<td>Often</td>
<td>1.24 (0.93 to 1.64)</td>
<td>1.24 (0.93 to 1.65)</td>
</tr>
<tr>
<td>Hours of exposure to news and information about COVID-19 on social networks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.77 (0.59 to 1.01)</td>
<td>0.73 (0.55 to 0.99)</td>
</tr>
<tr>
<td>2 to 5</td>
<td>0.76 (0.59 to 0.98)</td>
<td>0.74 (0.56 to 0.98)</td>
</tr>
<tr>
<td>6 or more</td>
<td>1.11 (0.84 to 1.47)</td>
<td>1.10 (0.81 to 1.49)</td>
</tr>
<tr>
<td>Hours of exposure to news and information about COVID-19 on television</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.88 (0.64 to 1.21)</td>
<td>0.87 (0.63 to 1.20)</td>
</tr>
<tr>
<td>2</td>
<td>0.91 (0.65 to 1.28)</td>
<td>0.92 (0.65 to 1.28)</td>
</tr>
<tr>
<td>3 or more</td>
<td>1.02 (0.75 to 1.37)</td>
<td>1.02 (0.75 to 1.39)</td>
</tr>
<tr>
<td>Hours of exposure to news and information about COVID-19 on the radio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 more</td>
<td>1.16 (0.95 to 1.41)</td>
<td>1.16 (0.95 to 1.42)</td>
</tr>
</tbody>
</table>

aOR: odds ratio.  
bAdjusted for gender, age group, education, cohabitation status, and income changes during the pandemic.

**Discussion**

**Principal Findings and Comparison to Prior Work**

This study found that older people, especially older women, were often exposed to information related to COVID-19 through television and social networks and that this had repercussions for their mental health, specifically GAD and stress.

The participants in this study were mostly White educated women aged 60 to 64 years who cohabited with 1 or 2 people in their own residence, received retirement income, and had no change in income due to the pandemic.

We hypothesize that our findings may be related to the income status of the study population, as this is a limitation for many older people. A lack of financial support and purchasing power limits access to the internet and to electronic devices. Social exclusion from internet access is considered one of the most important markers of socioeconomic inequality [9]. Moreover, the persistence of ageism can make older people digitally invisible, supporting the idea that older people do not have the necessary skills to make use of all the functions of technology [9,17].

One study inferred that older adults with 9 or more years of education are more likely to maintain internet use than older adults who had less education or who did not have access to school [18]. The proportion of internet users is higher among people with more education, those with a higher monthly family income, and those who are younger, which is in line with the results of this study. Older individuals with a lower educational level may have greater difficulty using and manipulating computers and cell phones and therefore use the internet less [17,18].
In line with this study, data from the Continuous Pesquisa Nacional por Amostra de Domicílios (National Household Sample Survey) [11] show that there are more women than men in Brazil. The Brazilian population is composed of 48.2% men and 51.8% women, and among older individuals, the percentage of women reaches 56%. In addition, women show greater receptivity, which ensures greater agreement and participation in opinion studies and interviews [19]. Media consumption increased during the period of social distancing, and although older people are part of the population with the lowest level of internet and digital media use, their access to and use of such media also increased during the pandemic [20,21].

Some studies indicate that social distancing and anxiety further increased digital screen time [20-23]. The use of the internet was promoted by video calls, which allowed greater contact between older people and their family and friends, and by apps that allowed delivery of food and medicine. These contacts, in addition to acting directly on health by promoting well-being and quality of life, helped reduce feelings of loneliness [22]. On the other hand, the continuous use of the internet and other means of communication contributed to increasing access to ill-organized information and continuous information overload [23].

This study found that television was the most used means of accessing information, followed by social networks. Older people reported that they were frequently exposed to information about COVID-19 on television and that their daily exposure was 3 hours or more.

Television is a medium that allows access to content produced by journalists, which suggests a certain level of confidence from the social point of view, although television may also promote content that is biased in favor of business, political, and even economic interests. During the pandemic, television briefly acquired centrality in Brazilian homes, because older people gathered around televisions in search of information about the disease. In emergency situations, social media is another useful channel for news, due to its rapid, real-time dissemination of specific, objective content [18,20].

Similarly, the literature shows that social networks and television are the main means of access to information in the pandemic [17,23-26]. A cross-sectional study conducted in Brazil with data from a virtual health survey revealed an increase in television-watching among adults during the pandemic [17].

A Brazilian study reported that during the pandemic television use averaged 3.31 hours, representing an increase of 1 hour and 45 minutes compared to the average time dedicated to television before the pandemic. Among the participants, those aged 60 years or older were the group who spent the longest average time watching television, which corroborates the data found in this study. The average time of use of computers or tablets was more than 5 hours during the pandemic, representing an average increase of 1 hour and 30 minutes compared to before the pandemic [27].

The hours and frequency of exposure to information are important data, because they can be indicative of information-seeking behavior, and they can potentiate infodemic content in the social context and the possible impacts of the infodemic on the mental health of the individual. Additionally, when investigating factors that increase protection and well-being regarding the use of the media, it is important to weigh the time spent in hours and the frequency of exposure to the media [6,28].

We found a significant association between infodemic variables, perceived stress, GAD, and the frequency of exposure to social networks. This suggests that exposure time and the source of information used by older people can impact their levels of anxiety and stress.

A recent German study reinforced the idea that the information conveyed by digital social media and traditional media, including broadcast television and radio, are linked to increased anxiety [28]. Conversely, the information provided by official sources and government websites is related to a decrease in anxiety [29]. Another study, conducted with 4872 adult Chinese citizens, found that older individuals who were frequently exposed to social media had a prevalence of anxiety of 22.6% and a prevalence of depressive disorders of 16.6% [14].

Research shows that in the context of the pandemic, being frequently exposed to alarming information about sick or deceased individuals increases the risk of mental disorders such as depression and anxiety [14,24,30]. Sensationalist content and misinformation generate a large supply of ideas that are difficult to process, causing symptoms of anguish and mental confusion.

In this study, mean perceived stress and GAD were higher among older participants who had no exposure to social networks. This agrees with studies [28-30] that point out that avoiding information can be an attempt at a defensive response and a form of emotional coping with infodemic stressors [28]. On the other hand, avoiding information can lead people to worry that they are missing important new information, generating stress and anxiety and showing that avoidance is a poor adaptive coping attitude [31].

The abovementioned German study showed that the choice to avoid information may be linked to a feeling that there is nothing that can be done to prevent the negative consequences of COVID-19. Participants who were “very concerned” about the risks to mental and physical health were also more likely to avoid or ignore the media. That analysis also revealed that a higher level of stress was associated with less access to social networks, especially among those who did not consider themselves to have good mental health [29].

Individuals tend to avoid exposing themselves to information when they associate it with aversive emotions or when the information might make it necessary to perform unwanted actions [31]. Indeed, the COVID-19 infodemic provoked thoughts about human mortality, sequelae of the disease, progression to the severe stage of the disease, and involved biosafety guidelines and recommendations that imposed new habits, including social distancing, to which a significant proportion of older people objected.

Thus, it is necessary to develop health education strategies appropriate to older individuals to respond to the infodemic and provide clear, specific, and objectively necessary information.
In addition, it is important to investigate health literacy (ie, the ability to access and use information to make appropriate health decisions) and digital literacy (ie, the ability to locate information in digital media, select it, access it, and use it to acquire knowledge) [32,33].

The media constitute an important element in the construction of an informative discourse, distributing information about diseases and their methods of transmission, prevention, treatment, and immunization, as well as reporting on the most recent research [19]. Reliable and accessible information is important to increase the population’s awareness of preventive measures, the importance of immunization, and the fight against disease progression [19,32].

Given the above, we emphasize the importance of public health policies on infodemic management that encourage social education among older people on how to seek and interpret information. A past study that discussed the public health research agenda for managing infodemics suggested that public health authorities should develop, implement, validate, and adapt tools to manage infodemics at acute public health events, taking into account the country-specific context, and invest and foster policy makers in the scientific community [34].

Limitations
A limitation of this study is the use of a web-based survey. This tool, which was chosen due to COVID-19 restrictions, limited the participation of many older people who do not have access to the internet or social networks, causing sample bias.

Another limitation was the profile of the participants, who were predominantly female, White, had completed elementary or higher education (even graduate education), lived in urban areas, cohabited with 1 or 2 people, had fixed incomes, and had incomes that were unaffected by the pandemic. These characteristics, which do not correspond exactly to the general Brazilian population, might have been protective against mental illness.

Conclusions
Excessive information can affect mental health, cause feelings of stress and anxiety, and affect the quality of life of older individuals. In a pandemic context, the severity of these effects may be magnified by obstacles to sociable behavior and health service and support networks.

Investigation of the infodemic and its impacts on mental health should be part of the anamnesis of older people, so that they can share their feelings about this phenomenon and receive appropriate psychosocial care.

The management of excessive information should be a subject of debate in public health. The infodemic phenomenon is complex, because it is centralized, multifactorial, and cross-cut by important political and sociocultural issues.

This study contributes to the scientific community by presenting quantitative data that demonstrate the association between infodemic variables and mental health. This study also helps fill a knowledge gap in an important thematic axis and represents an original investigation into the impacts of the infodemic on GAD, perceived stress, and major depression in the older Brazilian population.

Acknowledgments
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Data Availability
The data sets generated and/or analyzed during this study are available from the corresponding author upon reasonable request.

Conflicts of Interest
None declared.

References


Abbreviations

ANOVA: analysis of variance
GAD: generalized anxiety disorder
GAI: Geriatric Anxiety Inventory
PPS: Perceived Stress Scale

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