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Technological innovations to address social isolation and loneliness in older adults

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Technological innovations to address social isolation and loneliness in older adults

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Editorial: Technological innovations to address social isolation and loneliness in older adults

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Editorial on the Research Topic
Technological innovations to address social isolation and loneliness in older adults

Social isolation and loneliness are widely recognized as a global challenge for population aging (1). Mounting evidence has shown that both social isolation and loneliness are associated with increased risks of major physical, cognitive, and psychological morbidities as well as lower perceived wellbeing and health-related quality of life among older adults (2).

Among various policy and social service delivery approaches, innovative technologies have emerged as a promising solution to reduce social isolation and loneliness for this population, and/or to increase support to family members of older adults in need (3, 4).

While our research community continues to face the challenges of finding feasible and cost-effective solutions to improving social connection and support for older adults, the historical and global context of the COVID-19 pandemic has further highlighted the advantages of using digital technology to assist vulnerable populations such as older adults in both residential homes and institutional settings.

This Research Topic includes over 20 contributions from authors all over the world. Their papers represent the frontiers of the interface between the challenges of the need to address social isolation and loneliness among older adults and the research opportunities associated with the advancement of digital technologies. Several themes are emerging as summarized below.

1. Mobile technology use reduces loneliness

Mobile technologies have been instrumental in transforming the way in which older adults interact with each other, find information, and access resources to improve their health and wellbeing (5). Behaviors such as making video calls, participating in social media, or simply using the internet to search for information, can help improve social connection, reduce loneliness, and attain a higher quality of life.

In a narrative review of the literature describing the use of video calls in geriatric institutions between 2000 and 2021, Naudé et al. from France reviewed 15 studies focusing on the usability, acceptability, and effectiveness of video calls, and conducted a qualitative, deductive thematic analysis inspired by a Health Technology Assessment (HTA) multidimensional model. They found encouraging evidence for the feasibility of video call use in geriatric institutional settings,

and its efficacy in reducing social isolation among residents, while at the same time, identifying numerous technical, human-related, ethical, and organizational barriers to their use.

Using data from the 2016 wave of the US Health and Retirement Study, Byrne et al. analyzed the self-reported frequency of social technology use (e.g., communication through Skype, Facebook, or other social media with family and friends). They found that social technology use is less prevalent among rural older adults than urban and suburban-dwelling older adults. Among rural older adults, those who use social technology less frequently experience greater loneliness than urban older adults, suggesting the importance of considering rural disparities in designing social technology interventions for older adults.

Czaja et al. from the US analyzed the baseline data from a sample of older adults who participated in an intervention trial that examined the beneficial effects of a software system designed to both support access to resources and information and social connectivity. They found that loneliness was strongly associated with depression and self-ratings of health, and that having a smaller social network, more functional limitations, and limitations in engaging meaningful activities were associated with higher levels of loneliness and greater social isolation. They posit that information and Communication Technologies (ICTs) can be used to promote social connectivity and engagement.

Using a larger sample of older adults who participated in the China Longitudinal Aging Social Survey, Li et al. found that only a small percentage of older Chinese adults often used the Internet to engage in at least one activity, and that internet users were less likely to be depressed and had a higher level of cognitive function. They also found that among those who used the Internet more, the depression levels of socially isolated male participants were much lower than female participants, suggesting protective impacts of internet use.

Using data from one region in East China, Yang et al. examined the factors influencing the digital inclusion of older adults and the relationship between digital inclusion and quality of life. They found that attitudes toward technology were the most significant factors predicting their digital inclusion, and further, that digital inclusion was associated with higher quality of life among Chinese older adults. This research confirms the importance of ICT as an important pathway for wellbeing among older adults.

Using data from the China Longitudinal Aging Social Survey (CLASS), Xie et al. analyzed the effects of Internet use on the mental health of Chinese older adults and found that internet use increases depressive symptoms in older adults and that depressive symptoms are associated with female gender, younger age, high-income, non-rural residence, less educated, and living with others. They speculate that internet use may reduce actual in-person human relationships or actual social interaction. The discussion reinforces the long-standing caution for prudence in assessing and weighing the benefits and detriments brought about by new technology.

2. How technologies help those with cognitive impairments

While applauding the emergent positive impacts of ICT in reducing social isolation for older adults, it is also important to understand how technologies can benefit those with cognitive impairments and their caregivers (6, 7). Several research teams explored how ICT can help the caregivers of persons with dementia by increasing access to learning opportunities for knowledge and skills necessary to improve their capacity to care for both patients with dementia and themselves. In general, more research is needed to assess how technologies can assist those patients with varying levels of cognitive impairments.

Prophater et al. reported the effectiveness of an 11-month intervention in preventing social isolation and increasing mood among older adult residents of senior care communities (e.g., assisted living communities, and skilled nursing communities) during the COVID-19 pandemic in the US. The intervention included distributing personalized Wi-Fi-enabled iN2L tablets to the senior care communities to connect and engage residents and their families and providing a video-based learning platform. A survey of program staff indicated that residents struggled with loneliness and mood and that the tablet was useful in improving loneliness and mood and reducing risks of dementia or cognitive decline in residents, and allowing them to stay in touch with family and friends.

In a scoping review, Huisman et al. from the Netherlands showed that technology applications that target caregivers of persons with dementia can both lower caregiver burden and/or improve caregiver quality of sleep and reduce social isolation. Of interest, interventions may target the person living with dementia, their informal caregiver, or both.

Lydon et al. from the US conducted a narrative review of the research on social engagement in persons with mild cognitive impairment (PwMCI). They found that PwMCI may have different levels of social engagement than those experiencing typical cognitive aging, and in-person social engagement can have a positive impact on cognitive, emotional, and physical health for PwMCI. They note that very few intervention studies have targeted social engagement, but both in-person and technology-based interventions appear to have promising health and wellbeing outcomes.

3. New technologies beyond ICT for older adults at home

Digital technology not only has enhanced convenience and affordability for social connection, it also provides an array of new opportunities to enrich the daily lives of older adults (8). Through the examples of voice-control devices, games, or home-based sensor systems, we are peeping into a future where artificial intelligence (AI), internet of things (IOT), and ambient and wearable sensor technologies are increasingly interwoven with human behavior, offering new possibilities to enable the older adults with disabilities and functional limitations.

In a study aiming to understand the influence of personal voice assistants (PVA) on loneliness reduction among adults of advanced ages, Jones et al. from the US assessed 16 older adults using an Amazon Echo PVA for 8 weeks. They found that after the first 4 weeks of the intervention, participants reported significantly lower loneliness, and that relational greetings (i.e., user-initiated, friendly phrases) predicted loneliness reductions in the first 4 weeks and baseline loneliness predicted relational greetings with the PVA during the entire 8 weeks.

Corbett et al. from the US reviewed older adults' use of commercially available artificial intelligent virtual home assistants (VHA) (e.g., Amazon Echo, Google Nest) and found that VHAs are

perceived by many older adult users as "companions" and helpful for improving social connectedness and to reduce loneliness. Further research needs to address privacy concerns and other ethical issues as well as costs associated with VHA use as potential barriers to older adults' VHA adoption and use.

In assessing older adults' perception of two commercially available exergames, Freed et al. from the US found that greater enjoyment and the greater likelihood of future play were significantly related to a relatively younger age. Participants were highly motivated to do well on the games but reported lower scores for the likelihood of playing these games in the future. The preliminary results of this pilot study suggest that exergames may help address social isolation and loneliness.

A 12-month observational study in Switzerland evaluated a new in-home monitoring system that continuously monitored older adults' daily activities (e.g., mobility, sleep habits, fridge visits, door events) by an ambient sensor system and health-related events by wearable sensors. Pais et al. found that the majority of older adults, family caregivers, and support nurses reported that in-home sensors helped with staying at home, improved home care and quality of life, prevented domestic accidents, and reduced family stress.

4. Toward building a better community

The advancement of digital technology has helped older adults get better connected with their family members and friends, and also gradually changed many older adults' home environment, reflecting the WHO's call for more age-friendly environments in the UN Decade of Healthy Aging (9). Thus, some investigators explored the notion of a better neighborhood or community designed to bring broader social resources (e.g., volunteers, paid workers, and other "strangers"), *via* the advantage of technology, for the benefit of older residents.

Sandu et al. from the US regarded a good neighborhood as one that addresses loneliness and barriers to care faced by vulnerable populations such as older adults. They instituted a Good Neighbor Program of weekly phone calls conducted by student volunteers to community-dwelling older adults throughout the course of 1 year. The program not only provided another layer of support to identify and refer issues in older adults, it also had positive impacts on the caller.

The smart city agenda has attempted to bring about technological change whilst also improving access to urban resources for aging well. Li and Woolrych conducted a qualitative study with older people across three diverse neighborhoods in the city of Chongqing, China. They explored the experiences of older people living in a smart city in China to examine how the smart city and age-friendly agenda can be brought together to support positive social outcomes for older people. They identified the potential for improved health and wellbeing and social connectedness while identifying challenges such as widening social inequalities, issues of safety and security, and exclusion from the co-production of smart city policy and practice.

Paid and unpaid caregivers may respond differentially to the use of technology. In a nationwide survey of caregivers, Lee et al. from the US examined the association between communication technology use, perceived social support, and sense of belonging. They found that the use of communication technology was associated with an increased sense of belonging to their local community among paid caregivers, yet did not contribute to feelings of belonging among unpaid caregivers. Further research is needed to understand the effectiveness of different digital technology interventions in both populations.

An information and communication technology (ICT) training program is a promising strategy to reduce social isolation and loneliness for homebound older adults. Jiménez et al. from the US found that it is important to identify successful strategies for recruiting both volunteers and participants, to incorporate flexibility when delivering interventions to homebound older adults, and to monitor the participant-volunteer relationship through volunteer-completed reports to mitigate barriers to the successful implementation of the ICT training program.

5. Roles of technology during COVID-19 pandemic

The solicitation of articles for this Research Topic happened to fall into a special period of time when all of us, including researchers and older adults as well as their immediate supporters, were affected by a global social and health crisis caused by the COVID-19 pandemic (10). The pandemic not only resulted in significant disruption to the daily living of many people, leading to potential exacerbation of their physical and emotional distress, but it also increased the number of older adults who were socially isolated as many countries issued stay-at-home orders and numerous social-distancing measures (11). Several articles highlighted the positive roles of mobile technology or technology-enabled services in helping older adults through the very challenging period of the pandemic.

The COVID-19 pandemic interrupted both life and research. In examining the effects of a 12-week therapist-supported multicomponent mobile app-delivered intervention among middle-aged and older adults, Gould et al. found those who were enrolled prior to the COVID-19 pandemic experienced a significant increase in mental health quality of life (QoL) and a decrease in loneliness during the intervention; those enrolled after the pandemic began experienced a comparable increase in mental health QoL, while the decrease in loneliness during the period of mandated isolation did not hold.

The COVID-19 pandemic also led to a shift in some service programming from onsite to virtual. Sanchez-Villagomez et al. in the US noted that a hospital-based education program that used varied online approaches reached a substantial increase in program reach between April and August of 2020. Most participants reported a gain in knowledge and self-management skills and that virtual programming helped to foster social connectivity, helped to build a daily routine, and positively impacted mental and physical health despite the quarantine orders.

In a Canadian survey of older adults during the COVID-19 pandemic, Horst et al. found that many older adults felt isolated in 2020, regardless of most demographic factors (e.g., age, gender, education, disability) that were previously associated with increased isolation risk. Given that technology proficiency was seen as an independent, modifiable factor in reporting less isolation, future efforts to contain social isolation should consider training programs for older adults to improve technology confidence, especially in an increasingly digital world.

Strict measures practiced during the COVID-19 pandemic, such as preventing family members from visiting nursing homes for

several months, were likely to have enhanced feelings of loneliness and isolation in LTC residents. Given that ICT use has been shown to help older adults maintain social interaction, Gallistl et al. from Europe argue for policy recommendations to enhance and support LTC residents' digital engagement.

In fall 2022, the WHO predicted that "the end of the COVID-19 pandemic is in sight" (12), though there are still over half a million new cases every day in the world, and another Winter is approaching signaling a potential new surge (13). Despite the growing appreciation of digital technology and virtual social contacts we have experienced over the past 3 years, we know that for many older adults, the feeling of loneliness and the fact of isolation from one another will continue. So will our optimism in believing that progress will eventually be made through scientific efforts by our resilient research community and dedicated public health practitioners across the globe.

Author contributions

HC and SL conceived the original idea and contributed to the development of the first draft. SL and MO edited multiple versions of the manuscript. All authors critiqued the subsequent drafts. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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ORIGINAL RESEARCH
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Evaluation of 1-Year in-Home Monitoring Technology by Home-Dwelling Older Adults, Family Caregivers, and Nurses

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Introduction: Population aging is increasing the needs and costs of healthcare. Both frailty and the chronic diseases affecting older people reduce their ability to live independently. However, most older people prefer to age in their own homes. New development of in-home monitoring can play a role in staying independent, active, and healthy for older people. This 12-month observational study aimed to evaluate a new in-home monitoring system among home-dwelling older adults (OA), their family caregivers (FC), and nurses for the support of home care.

Methods: The in-home monitoring system evaluated in this study continuously monitored OA's daily activities (e.g., mobility, sleep habits, fridge visits, door events) by ambient sensor system (DomoCare®) and health-related events by wearable sensors (Activity tracker, ECG). In the case of deviations in daily activities, alerts were transmitted to nurses via email. Using specific questionnaires, the opinions of 13 OA, 13 FC, and 20 nurses were collected at the end of 12-months follow-up focusing on user experience and the impact of in-home monitoring on home care services.

Results: The majority of OA, FC, and nurses considered that in-home sensors can help with staying at home, improving home care and quality of life, preventing domestic accidents, and reducing family stress. The opinion tended to be more frequently favorable toward ambient sensors (76%; 95% CI: 61–87%) than toward wearable sensors (Activity tracker: 65%; 95% CI: 50–79%); ECG: 60%; 95% CI: 45–75%). On average, OA (74%; 95% CI: 46–95%) and FC (70%; 95% CI: 39–91%) tended to be more enthusiastic than nurses (60%; 95% CI: 36–81%). Some barriers reported by nurses were a fear of weakening of the relationship with OA and lack of time.

Discussion/Conclusion: Overall, the opinions of OA, FC, and nurses were positively related to in-home sensors, with nurses being less enthusiastic about their use in clinical practice.

Keywords: gerontechnology, patient satisfaction, monitoring technologies, home care, older people

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INTRODUCTION

The population is aging in Europe and worldwide (1), including in Switzerland in which people over 65 years of age are anticipated to account for more than 25% of the population by 2050 (2). Population aging combined with the high costs of healthcare brings many challenges for healthcare systems, long-term care, and management of age-related chronic diseases (3). A recent study underlines that 79% of health costs in Switzerland are linked to chronic diseases (4, 5). With population aging, the prevalence of chronic diseases is increasing, resulting in rising healthcare needs and increasing costs. Additionally, both frailty and chronic diseases affecting older people reduce their ability to live independently. However, most older people prefer to age in their own homes (6, 7).

In response to these challenges, monitoring, and assistive technologies, such as emergency help systems, vital sign monitoring, or fall detection systems, can be a solution to support home care of older people to help them stay independent and active for a longer time (8–11). Currently, ambient sensors (12–15), also known as ambient living sensors, and wearable devices (16, 17) are used in the homes of older people to monitor changes in health status, to detect falls, or to monitor activities of daily living (18–23). Such technologies can allow older people to better connect and communicate with their healthcare professionals as well as with their families.

A literature review on monitoring technologies has suggested that a combination of monitoring technologies including ambient and wearable sensors technologies is probably the most effective solution in independently living older people (24). However, such an in-home monitoring system needs to be evaluated in a real-life setting to demonstrate the potential to prolong independent living of older people (24).

The objective of this 12-month observational study was therefore to evaluate the usability, functionality, and effects of a new in-home monitoring system—combining ambient and wearable sensors—among home-dwelling older adults (OA), their family caregivers (FC), and nurses for the support of home care, focusing on their end user experience and the impact of these technologies on the daily practice in home care service (25).

MATERIALS AND METHODS

Study Design and Setting

This 12-month observational study was conducted among older people living independently at home and followed by nurses from NOMAD, the Neuchâtel public home care association, located in Switzerland, between January 2017 and July 2018. The study was approved by the Ethics Committee of the canton of Vaud, Switzerland (CER-VD ID: 2016-00762), and conducted based on principles declared in the Declaration of Helsinki. A written informed consent was obtained from all participating patients before study participation. We obtained the copyright holder permission to use and publish on the ambient sensor system (DomoCare®) by DomoSafety S.A.

Study Participants and In-Home Monitoring System

Patients for participation were identified and recruited by NOMAD nurses in collaboration with a research assistant (BP) through the NOMAD database if they met the following inclusion criteria: (1) home-dwelling older adults (OA $\geq$70 years) living alone at home and without pets; (2) followed by nurses from NOMAD, Neuchâtel public home care association; (3) speak and read in French. Exclusion criteria were (1) severe cognitive impairment unable to follow study protocol (clock-drawing score $\geq$ 4); (2) skin problems, such as irritations, itching, serious redness; (3) undergoing dialysis; (4) not willing to comply with the study protocol; (5) unable to understand the study aim; (6) hospitalization planned in a short period of time.

After potential eligible patients' screening, patients who were likely to meet inclusion criteria were approached in person during a phone call or a visit of research assistant (BP), given an information letter if they expressed an interest in participating, and scheduled an appointment at home. Once the eligible patient agreed to participate and provided a written consent form, an in-home monitoring system comprising the ambient sensors [DomoCare®, DomoSafety S.A, Lausanne, Switzerland (26)] and wearable sensors (ECG, Activity tracker) was installed, respectively at home and on the patient's chest and wrist. In-home monitoring was conducted for 12 months.

Data Collection and In-Home Monitoring System

During the 12 months of follow-up, the in-home monitoring system continuously monitored different OA's daily activities (e.g., mobility, sleep habits, fridge visits, door events) by ambient sensors (DomoCare®) and health-related events (e.g., physical activity and mobility, heart rate, skin temperature) by wearable sensors (Activity tracker, ECG). More precisely, the following data were recorded by wearable sensors: ECG signal, heart rate, heart rate variability, skin temperature, and respiration rate, as well as physical activity and mobility detected by accelerometer. The ECG sensor of type Preventice BodyGuardian was composed of a small and light battery powered device that was directly applied on the chest of the OA using a dry electrode and silicone-based adhesive patch. The data of the ECG sensor was automatically collected and transferred wirelessly from the sensor to a dedicated mobile phone and uploaded to servers for further analyses. The wearable Activity tracker, worn on the wrist of OA, was recorded and transmitted physical activity data (e.g., movement, number of steps) as well as heart rate.

Ambient motion sensors, installed in each apartment, recorded the OA's daily activities by passive infrared sensor (PIR) technology placed in the living room, bedroom, kitchen, and bathroom. Additional sensors were placed on the fridge and entrance door, measuring opening and closing of the door, and under the bed mattress, measuring bed presence, sleep cycles, respiration, and vital signs. The collected data were transmitted to servers for analysis by a base station. Data were then interpreted and subjected to trend analysis to detect changes in ADL and prevent changes in health status. In case of deviations in activities

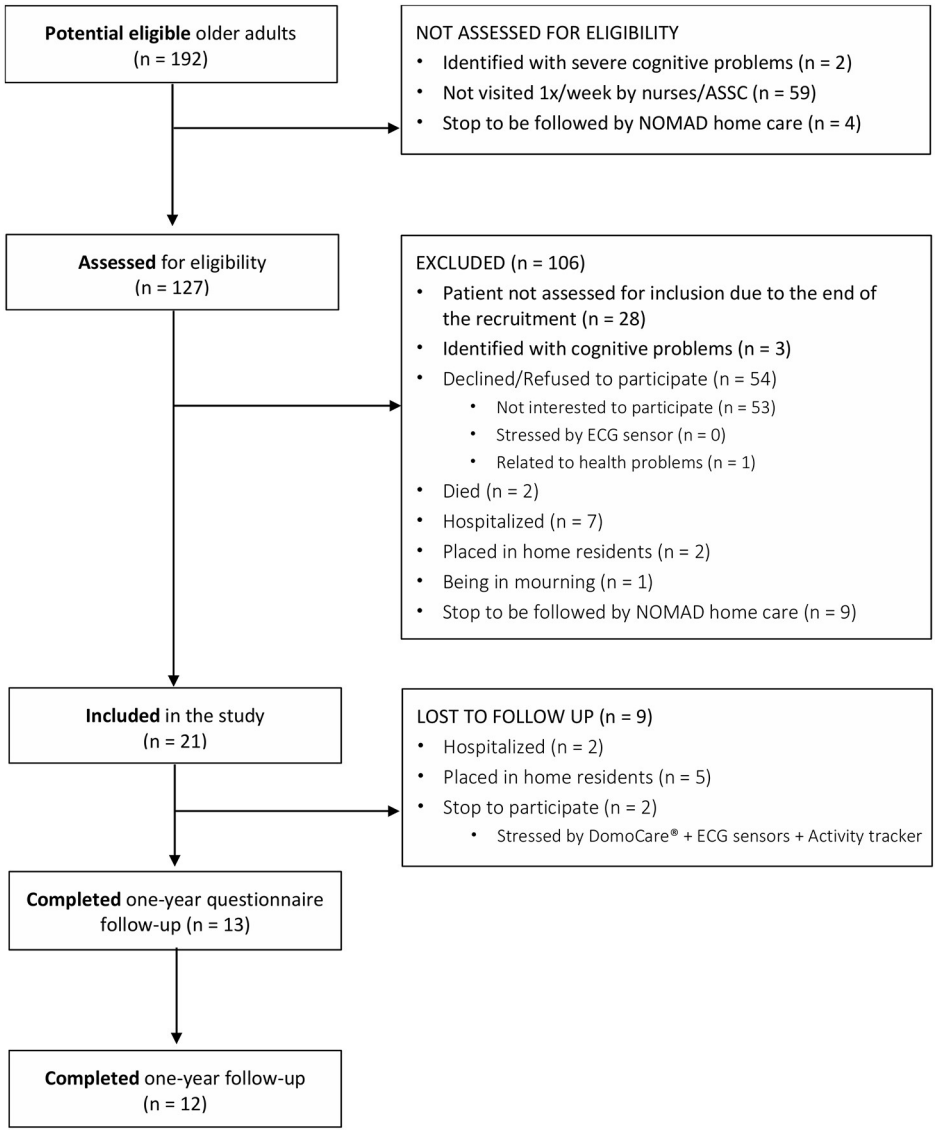

FIGURE 1 | Flow diagram of home-dwelling older adults.

of daily living (e.g., changes in mobility), alerts were transmitted to nurses via email, using a report with weekly patient's activity graph and information summarizing the deviation detected by ambient sensors (e.g., decrease of patient's mobility for 3 days).

Data Collection and Satisfaction of Home-Dwelling Older Adults, Family Caregivers, and Nurses

At the end of follow-up, specific self-administered mailed questionnaires were used to obtain users' satisfaction of OA, their family caregivers (FC), and nurses related to the in-home monitoring system and its impact on home care services. There were 20 nurses and 12 OAs. Nurses usually have care for several OAs and conversely OAs are usually cared for by more than one nurse. For each of the 20 nurses invited to respond to the questionnaire, an associated patient was randomly selected. Random selection was conducted by a statistician and restricted to combinations including the 12 OAs. This process had no impact on data collection.

Data were collected among 13 OA who completed the 1-year questionnaire, 13 family caregivers who play a central role as full partner in care and well-being of OA, and 20 nurses. Semi-structured interviews face-to-face or phone calls were conducted by a research assistant (BP) to complete the answers of the questionnaires described below.

The questionnaires filled by OA and nurses were based on the French version of the instrument titled the Quebec User Evaluation of Satisfaction with assistive Technology (QUEST) by Demers et al. (27), and the questionnaire filled by FC

TABLE 1 | Baseline characteristics of included older adults.

Characteristics	
Number of patients	**21**
Men/women, *n*	11/10
Mean age, years (*SD*) [range]	85 (7) [72–96]
Mean body mass index, kg/m^2 (*SD*)	26 (5)
Marital status	
Single, *n* (%)	1 (5%)
Married, *n* (%)	0 (0%)
Divorced, *n* (%)	2 (10%)
Widowed, *n* (%)	18 (86%)
Nationality	
Swiss, *n* (%)	19 (90%)
No-Swiss, *n* (%)	2 (10%)
Comorbidities	
Current smoker (≥1 cigarette/day), *n* (%)	0 (0%)
Cardiovascular diseases, *n* (%)	16 (76%)
Diabetes mellitus, *n* (%)	4 (19%)
Hypertension, *n* (%)	15 (71%)
Dyslipidaemia, *n* (%)	8 (38%)
Chronic kidney disease, *n* (%)	0 (0%)
Number of drugs, *n* (SD) [range] [median]	**9 (5) [3–20] [9]**
Polymedication (5 drugs or more), *n* (%)	19 (90%)
Using a weekly pillbox, *n* (%)	17 (81%)

SD, standard deviation.

was based on the caregiver quality of life scale developed and validated in France from data of the Pixel studies (28). These three questionnaires included open- and closed-ended response options, with additional questions on OA, FC, and nurse opinions', satisfaction, and practical experiences related to the in-home monitoring.

The questionnaires assessed 4 items: (1) opinion on the usefulness of ambient and wearable sensors; (2) satisfaction of OA, FC, and nurse with ambient and wearable sensors; (3) impact of sensors on the relationship between OA, FC, and nurse; (4) impact on in home care practice (integration and barriers). Answers to questionnaires were dichotomous (yes/no) or graduated on a five-point Likert scale, ranging from "a lot" to "not at all."

The construction, relevance, and comprehensiveness of questionnaires were assessed among five OA and one NOMAD nurse to ensure that they were easily understandable, well-defined, and accurately addressed the goals of the study.

Statistical and Data Analysis

Descriptive statistics were used to present baseline characteristics of OA and results related to ambient and wearable sensors as number, percentage, and score average. Overall opinion was calculated as weighted percentage. For the main results, 95% binomial confidence intervals (CI) were built around this percentage (command stata: cii proportion), i.e., the overall opinion and satisfaction of participants. All statistical analyses were performed using Stata software version 15.0 (Stata Corp, College Station, TX, USA) and Excel.

TABLE 2 | Opinion on the usefulness of ambient (DomoCare®) and wearable sensors (Activity tracker, ECG) to help staying at home, improving home care, improving quality of life, preventing domestic accidents, or reducing family stress.

	Older adults (*n* = 13) (%)	Family caregivers (*n* = 13) (%)	Nurses (*n* = 20) (%)	Average (*n* = 46) (%)
DomoCare®	82	80	69	76
Activity tracker	63	69	63	65
ECG sensor	76	60	49	60
Average	74	70	60	

RESULTS

The study design and flow-chart of patients are presented in **Figure 1**. Among the 192 potential eligible OA, 127 OAs were assessed for eligibility, 54 (42.5%) refused to participate, and 52 (40.9%) were excluded during the process (e.g., hospitalization, cognitive problems, death, placed in home residents). A total of 21 were included in the study, and 12 completed the 1-year of follow-up. The remaining 9 patients could not be contacted as a result of hospitalization and institutionalization. A total of 13 patients completed the 1-year questionnaire follow-up.

Characteristics of Patients

The baseline characteristics of the 21 included patients are shown in **Table 1**. The mean age was 85 years, half were men, and half received home care for more than 1 year. Patients took on average 9 drugs daily, 90% of patients were treated with 5 drugs or more per day, and 81% reported using a weekly pillbox to facilitate their drug intake. During the follow-up, 43% of patients were hospitalized at least once. Most patients were diagnosed with comorbidities, such as cardiovascular diseases, hypertension, dyslipidaemia, and diabetes.

Overall Opinion and Satisfaction

The majority of OA, FC, and nurses considered that in-home sensors (ambient and wearable) can help staying at home, improving home care and quality of life, preventing domestic accidents, and reducing family stress (**Table 2**). The opinion tended to be more frequently favorable toward ambient sensors (76%; 95% CI: 61–87%) than toward Activity tracker (65%; 95% CI: 50–79%) and ECG (60%; 95% CI: 45–75%). On average, OA (74%; 95% CI: 46–95%) and FC (70%; 95% CI: 39–91%) tended to be more enthusiastic than nurses (60%; 95% CI: 36–81%).

Opinion and Satisfaction on the Ambient Sensor System (DomoCare®)

As shown in **Figure 2**, most of OA and FC rated higher ambient sensors (DomoCare®) in helping staying at home (OA: 100%, FC: 85%), improving home care (OA: 100%; FC: 92%), preventing domestic accidents (OA: 85%; FC: 85%), and reducing family stress. The FC (69%) rated higher in-home sensors in

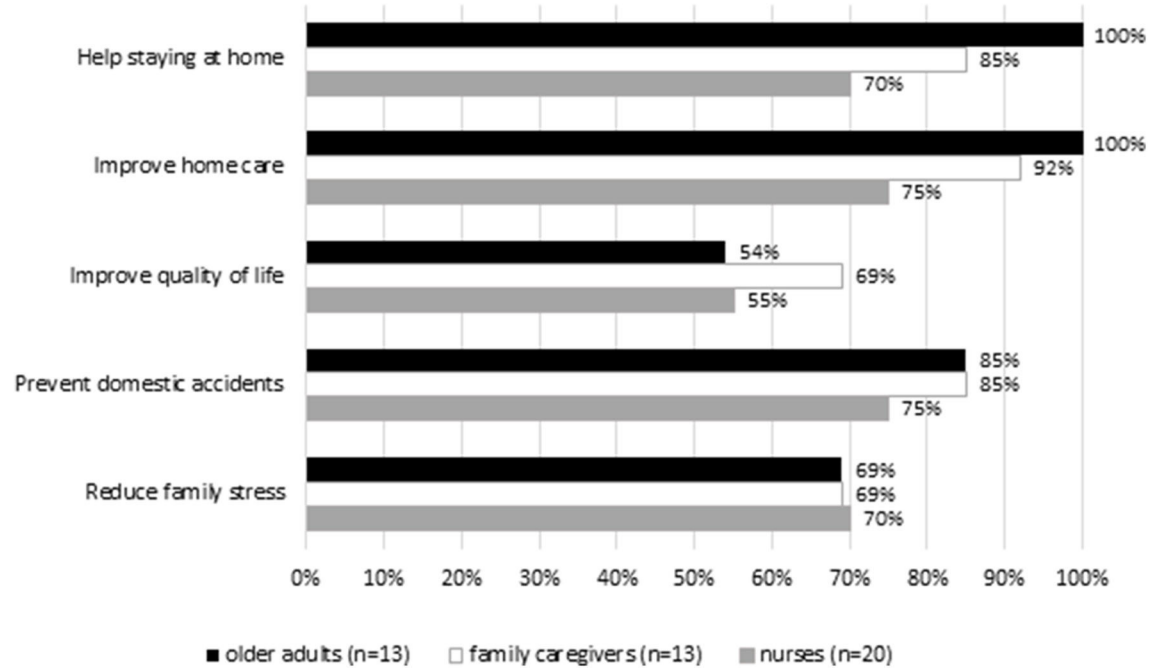

FIGURE 2 | Opinion on the ambient sensor system (DomoCare®).

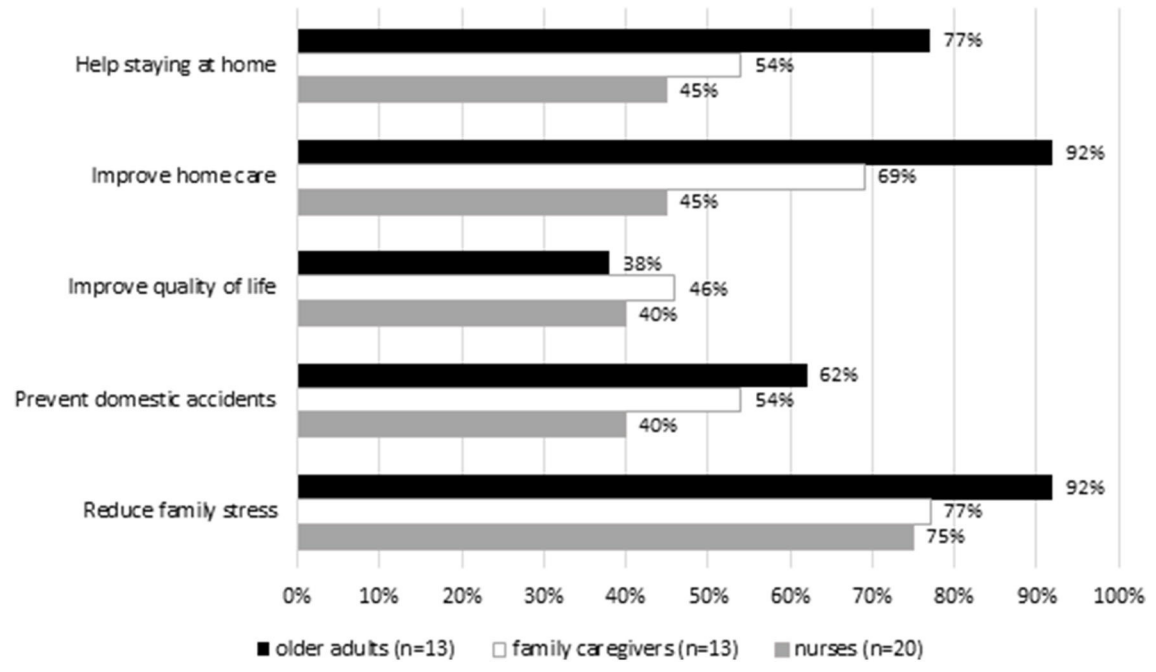

FIGURE 3 | Opinion on the wearable sensor (ECG).

improving quality of life compared to OA (54%) and nurses. More than half of OA (69%), FC (69%), and nurses (70%) considered ambient sensors can help reducing family stress. Overall, the majority of OA were satisfied with DomoCare®. Nurses tended to be less enthusiastic than OA, particularly regarding the technical (e.g., dimension, solidity) and practical settings of ambient sensors (e.g., ease of installation and use; **Supplementary Figure 1**).

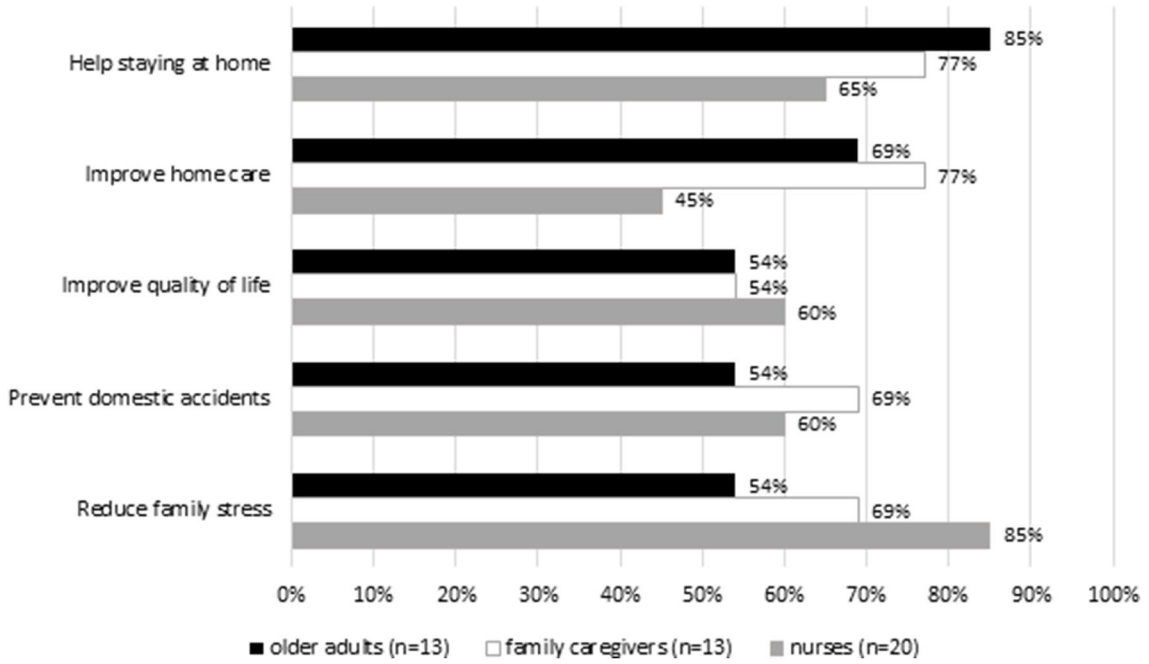

FIGURE 4 | Opinion on the wearable sensor (Activity tracker).

Opinion and Satisfaction on the Wearable Sensors (ECG and Activity Tracker)

Regarding the wearable sensors (**Figures 3**, **4**), most of OA and FC rated higher activity tracker in helping staying at home (OA: 85%; FC: 77%) and improving home care (OA: 69%; FC: 77%) compared to ECG. Most nurses rated higher activity tracker in improving quality of life (60%) and reducing family stress (85%). Regarding the ECG, the majority of the OA (92%), FC (77%), and nurses (75%) underlined that ECG can help reduce family stress. More than half of OA, FC, and nurses were skeptical regarding the prevention of domestic accidents for the wearable sensors [activity tracker (OA: 54%; FC: 69%; nurses: 60%); ECG (OA: 62%; FC: 54%; nurses: 40%)]. Overall, OA and nurses were satisfied with the Activity tracker and ECG. However, nurses tended to be less enthusiastic than OA, particularly with ECG, reporting that wearable sensors should be made smaller, lighter, and more comfortable (**Supplementary Figures 2**, **3**).

Events and Nurse Interventions

A total of 76 events were detected by DomoCare® (on average 4 events/patients; range 0–12 events). Each of them generated a preventive report validated by a research assistant (BP) and was transferred to NOMAD nurses by email. Events corresponded to changes in mobility behavior (26/76, 34%), in toilet usage frequency (24/76, 32%), in fridge usage (11/76, 14%), in entrance door usage (4/76, 5%), in time spent out of home (2/76, 3%), and in time spent in bed (9/76, 12%). For all events, nurses followed up with a home visit.

Integration of In-Home Monitoring Technology in Home Care Practice

Overall, the majority of nurses considered in-home sensors (DomoCare®: 65%; ECG: 55%; Activity tracker: 70%) easily implementable in their practice. However, nurses considered work overload, lack of time, and cumbersome procedures, especially for DomoCare® and ECG, and fear of weakening of the relationship with OA, as barriers to implementing in-home sensors (**Supplementary Figure 4**). Less than 50% of nurses reported lack of remuneration as a barrier. Finally, the majority of OA, FC, and nurses reported that they would like to continue using in-home sensors in case of insurance reimbursement.

DISCUSSION

This 12-month observational study showed that the majority of OA, FC, and nurses valued in-home monitoring systems including ambient and wearable sensors, notably to help staying at home, improving home care, preventing domestic accidents, and reducing family stress. On average, OA and FC tended to be more enthusiastic than nurses about this in-home monitoring system. Moreover, some barriers were reported by nurses, such as a fear of weakening of the relationship with OA and an excessive surveillance. Overall, the opinions of OA, FC, and nurses were positively related to in-home technology, with nurses being less enthusiastic about their use in clinical practice.

Comparison With Other Studies

Our findings suggested a variety of benefits and positive potential impacts of in-home monitoring on quality of life

of OA and nursing home care services. As described by previous studies (29–34), the majority of OA, FC, and nurses were not familiar with in-home monitoring technologies. However, they considered that such technologies can be relevant in the future by improving the quality of care among OA living independently at home. Moreover, the previous studies underlined that the acceptance and the use of in-home technologies by OA were often influenced by social network and pointed work overload of nurses, cost, and lack of funding to be barriers to implement in-home monitoring technologies.

In our study, OA and FC tended to be more enthusiastic than nurses regarding new in-home technologies. These results are consistent with other studies (29–34) showing that OA perceived in-home technologies as a viable home care solution, which can prolong their time living at home, whereas nurses had concerns that such technology could weaken their relationship with OA and worsen their work conditions.

Strengths and Limitations of the Study

Strengths of our study are mainly (1) the close collaboration between OA, FC, nurses, researchers, and engineers; (2) the innovative use of assistive and digital technologies designed to support independent community older adults; and (3) the collection data on the use of in-home monitoring devices. Furthermore, all OA who completed the 12-month follow-up, all nurses, and all FC filled out the questionnaires. However, we acknowledge some limitations to our study. Due to logistical and financial reasons, the study sample was small. There was also a high loss to follow-up notably due to hospitalization and moving to a nursing home, which are frequent events among this type of patients. Furthermore, for logistical reasons, the study was conducted in only one place, which limits its external validity. Further studies are therefore needed to evaluate the transferability of our findings to other regions and populations. We did not use a specific theoretical acceptance model in this study, but further studies would gain from doing so. Finally, we tested one in-home monitoring system and a given set of sensors, and our findings may therefore not apply to other systems or individual sensors.

Future Perspective

In conclusion, OA, FC, and nurses were very or quite positively related to DomoCare®, Activity tracker, and ECG sensors and reported that in-home monitoring technologies may facilitate home care and opened good perspectives for use in home care practice. Further studies, at a larger scale, are needed to evaluate how this type of in-home monitoring can help patients stay longer at home, improve health care management, and reduce healthcare costs. Further, some manufacturing improvements (e.g., development of sensors that are smaller, lighter, and more user-friendly and comfortable for OA, as well as advances in machine learning for detection of specific events at home) and training of nurses in the use of these monitoring systems should be considered, to ease their use, increase comfort of end-users, and preserve and strengthen the relationship between OA and nurses are key for implementing these new technologies in nursing home care practice (32–39).

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/**Supplementary Material**.

ETHICS STATEMENT

The study was reviewed and approved by CER-VD: Cantonal Ethics Committee of Vaud on Research involving humans. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BP, PB, GD, TN, NS, HS, DG-P and VS designed and planned the study. DomoSafety S.A. installed and maintained the wearable sensors (ECG, Activity tracker) and ambient sensor system (DomoCare®) monitoring the participants. BP and NS measured participants. BP and VS analyzed data from the questionnaires filled out by the participants, their families and nurses at the end of follow-up, and wrote the manuscript. All authors reviewed and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2020.518957/full#supplementary-material

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Conflict of Interest: PB and GD are employed by DomoSafety S.A., which is the manufacturer of the displayed ambient sensor system (DomoCare®).

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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OPINION
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COVID-19 as a "Digital Push?" Research Experiences From Long-Term Care and Recommendations for the Post-pandemic Era

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Keywords: inequality, digital divide, gerontology, long-term care, ICT

BACKGROUND

Health authorities and governments worldwide label older adults as a "risk group" for more serious and possibly fatal illness associated with SARS-CoV-2 (COVID-19) (1). Those older adults living in long-term care (LTC) are considered especially prone to more serious and fatal disease following a COVID-19 infection (2). Consequently, measures requiring LTC residents to shelter in place and maintain physical distancing from others have been enacted in many countries during the pandemic. However, these measures make this group particularly prone to isolation, especially because the measures have prevented family members from visiting nursing homes for several months. Researchers have posed concerns that these particularly strict measures are likely to enhance feelings of loneliness and isolation in LTC residents (3).

The use of digital technologies by LTC residents has been painted as a hopeful alternative to face-to-face contact during the COVID-19 pandemic. Several digital solutions have been suggested to decrease the social isolation of older adults, such as Skype, FaceTime, or Zoom, which allow LTC residents and their families to interact virtually (3). Indeed, the use of information and communication technologies (ICT), such as the Internet, offers many benefits (4) for older adults living in nursing homes who wish to stay in contact with others while following COVID-19 social distancing measures. The Internet has particularly been shown to play an important role in distance-based social contact during the coronavirus pandemic (5).

Although ICT use might help older adults maintain social interaction, LTC residents may also feel socially excluded because they lack the necessary skills and equipment to be included in the digital society (6, 7). Studies have shown that nursing home residents are less likely than community-dwelling older people to take advantage of the opportunities provided by modern ICT (8) for the following reasons: they might (a) opt not to use the Internet, (b) live in an environment where Internet access is not available, (c) not have sufficient support from inside or outside their nursing homes, and (d) have physical or cognitive limitations that limit or prevent ICT use without assistance (9, 10). Furthermore, when nursing homes isolate their residents from outside contact, they may prevent individuals from ICT support from outside the facilities. Thus, the tremendous barriers to ICT use in nursing homes are not likely to be handle everywhere during the pandemic, when LTC systems are under a considerable amount of general pressure with coping the current pandemic.

This opinion article investigates and discusses the evidence for a "digital push" in LTC during the COVID-19 pandemic by referring to data regarding Internet use from 259 nursing home residents.

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Building on these findings, the article provides research and policy recommendations to enhance and support LTC residents' digital engagement during the COVID-19 pandemic and beyond.

THE DIGITAL DIVIDE IN LONG-TERM CARE AND ITS CHANGES DURING THE PANDEMIC

Research has shown that more residents of nursing homes are using the Internet; however, this Internet use is at a lower level than that of younger adults (11). Furthermore, specific LTC groups are more like to use ICTs, while others are not likely to engage in ICT use. For example, Seifert and Cotten (8) showed that only 21% of retirement home residents in Zurich (Switzerland) used the Internet. Compared to non-users, Internet users were more likely to be younger, healthier, and more functionally unimpaired (8). Of the participants in this study, only 12.8% reported owning a smartphone, and even fewer reported owning a tablet (4.5%). Similar results were generated by a study in Germany that involved 1,863 people aged 80 years and older who lived in private households and LTC facilities (11). Only 3% of the participants in LTC facilities reported using Internet-connected ICT devices. ICT device adoption was associated with functional health, chronological age, education, and interest in technology (11). The results of these studies showed that a minority of LTC residents used ITCs before the pandemic and that the more educated, younger, and healthier residents were more likely to use ICTs.

However, current research also showed that institutional context and ICT infrastructures in nursing homes are important aspects of digital engagement in LTC (10, 12). Studies conducted before the COVID-19 pandemic found that ICT availability is often limited in LTC facilities, which have a significant deficiency of ICT infrastructures (13, 14). This deficit also includes a lack of ICT skills among the care staff, as well as the staff's reserved attitude toward technology use within LCT facilities (15). The COVID-19 pandemic further complicates this complex relationship between individuals' ability to use ICT and the institutional infrastructures that govern the access to ICT in LTC. The ongoing pandemic has created new awareness of the existing limitations of these facilities' current ICT infrastructures (16–18), but it has also restricted opportunities to remove these institutional and individual barriers to ICT.

RESEARCH ON INTERNET USE IN LONG-TERM CARE DURING THE PANDEMIC

Between August and September 2020, we included some ICT-related questions in a bigger study about the coping strategies of residents living in nursing homes during the pandemic (19). The representative sample included 259 residents from 16 nursing homes evenly distributed across Austria. The participants, who were all LTC residents for at least 3 months before the study, filled out a standardized questionnaire with closed questions. The age range of the sample was 47–101 (mean age: 83 years). Of the respondents, 74% were female, and 26% were male. About one-third (32%) had lived in LTC less than a year, while another third (32%) had lived in LTC for more than 4 years. In total, 56% of the respondents reported multiple limitations in daily living activities (e.g., personal hygiene, getting dressed, eating, taking a walk).

Concerning the digital engagement of the LTC residents during the COVID-19 pandemic, only a small percentage (9.2%) of the respondents reported using the Internet (4.1% "often" and 5.1% "sometimes") to stay in contact with their relatives. ICTs seemed to be particularly unpopular; the majority of respondents (99.3%) used the telephone to stay in contact with their families. While a need for more personal contact was apparent—half of the respondents (49%) stated that they felt lonely often (17%) or occasionally (32%)—digital solutions to combat this loneliness did not seem to be an option for residents in LTC.

The data also revealed that although levels of loneliness had remained high during the COVID-19 pandemic, ICT use had hardly increased among the respondents. When asked about the increase or decrease of Internet use during the pandemic-related lockdown in Austria (i.e., when contact restrictions were in place), 33.3% of the 42 residents (33.1% of the whole sample) who reported using the Internet stated that they used it more often during the lockdown, 31.3% used it the same amount, and 35.7% used it less often. In comparison, 37.1% of the telephone users ($n = 250$) reported using the telephone more often to stay in contact with relatives, while 55.5% of the Internet users ($n = 44$) reported using the Internet more often for this purpose.

Several assumptions can be made about this relatively small increase in digital engagement during the COVID-19 pandemic. First, as stated before, the ICT infrastructure and Internet use among LTC residents were both limited before the pandemic. Second, the ICT skill set of LTC residents may be lower than younger people; therefore, learning new ICT skills is more time-consuming for residents. Third, during the pandemic, LTC facilities do not have the personal resources necessary for organizing new ICT hardware for the residents or helping the residents learn ICT use. Finally, ICT support (e.g., from family and friends) from outside the LTC facilities was limited during the pandemic.

RECOMMENDATIONS FOR THE POST-PANDEMIC ERA

As seen above, an easy "parachuting in" of technology during the pandemic is not likely in LTC, mainly because the Internet is not the main medium for social interactions for older adults aged 80 years and older (11). A study in the US found that 27% of people aged 65 years or older still did not use the Internet, compared to <10% of adults under that age (20). In contrast, a representative survey conducted across European Union countries showed that 49% of people aged 50 years or older used the Internet (21); the same study showed that people older than 80 years spend less time online than people in the next highest age group (65–79 years) and that men and older adults with a higher educational or economic status are more likely to use the Internet. Furthermore, individuals' health, prior

experience with technology, social salience (Internet use among the members of their social network) and contextual factors, such as country-specific wealth and communication technology infrastructure, are predictors of Internet usage by older adults. Similar differences in the use of the Internet are seen with other emerging technologies (22, 23). Furthermore, institutional mechanisms in LTC are not sufficient for supporting older adults' appropriation of digital technologies (8, 9, 12).

Based on the presented data from Austria, a simple "parachuting in" of digital technologies in LTC will not be enough to ensure sustainable engagement with ICT that actually prevents loneliness and social exclusion during the COVID-19 pandemic. Internet use in LTC is a complex and relational process that is highly dependent not only on the interest and motivation of residents but also, and even more importantly, on institutional mechanisms, support structures, and opportunities.

Therefore, the hope in a "digital push" spurred by the COVID-19 pandemic may be just that—optimism in the face of overwhelming social isolation for older LTC residents. In that sense, current discourses surrounding digital solutions that aim to support the social inclusion of older LTC residents must be reconsidered. This consideration should determine whether the current discourses are actually designed to provide help to LTC residents or are part of a general techno-optimism that often accompanies discourses concerning digitalization and later life (24). Techno-optimism characterizes demographic change as a problem and (digital and assistive) technologies as the adequate solution to solve this problem.

Given the rapid expansion of ICT in society, discussion of further recommendations is worthwhile. Based on the discussion and findings outlined above, we recommend the following:

(A) Understanding digital engagement in LTC as a process, rather than an intervention, that requires continuous engagement and support, as well as adequate infrastructures and skills, for both residents and care staff.
(B) Developing and implementing a different perspective on digital technologies in LTC that understands technologies not merely as an artifact or an instrument but also as a learning process that needs to be professionally supported.
(C) Supporting LTC units in building an adequate infrastructure to enable the digital engagement of their residents by producing public policy and applying research projects.
(D) Giving LTC residents the ICT skills and training that they need by providing free-of-charge learning opportunities and ICT support (e.g., from ICT-trained recreational therapists) within the LTC facilities.

CONCLUSION

When the proper support is provided ICT offers unique and innovative opportunities for older adults living in nursing homes. Older adults, their relatives, and their professional caregivers can take advantage of these digital tools to improve their daily lives. However, the use of technology can be challenging, especially when older adults lack access to new tools or digital skills and are pushed into digital solutions, especially in times of social distancing. Developers, practitioners, and researchers in the field must be aware that the appropriation of digital technologies in LTC is a complex process that requires a variety of actors to be successful and sustainable. Digital engagement in LTC calls for appropriate infrastructures that support older adults' engagement in ICT; these infrastructures include adequate training and learning opportunities for residents and care staff, stable Internet connection, and access to adequate devices. Therefore, future studies should provide practical guidelines that consider the older adult user contextually and his/her individual characteristics (25).

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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COMMUNITY CASE STUDY
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Shift to Virtual Self-Management Programs During COVID-19: Ensuring Access and Efficacy for Older Adults

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Background: The COVID-19 pandemic resulted in significant uncertainty and disruption to many aspects of daily living, including physical activity, socialization opportunities, and access to healthcare services. Under these conditions, at-risk older adults are even more likely to be inactive and isolated, leading to potential exacerbation of musculoskeletal and chronic conditions and emotional distress. This case study provides an overview of our experience and best practices developed during our shift from onsite programming to virtual.

Methodology: HSS utilized varied online approaches, including phone/video conference classes, webinars, on-demand videos and email campaigns to successfully transition programs. Due to this shift, HSS changed its evaluation to an online approach, using a mixed method to adequately assess the impact of programs.

Results: Between April and August 2020, our virtual programs reached 428,766 participants, resulting in a 10,807% increase in program reach. Most participants assessed were 60 years or older (72%) and reported knowledge (85%) and self-management skills (83%) gained as well as high program satisfaction (90%). Analyses of program data did not show any statistical significant difference in self-reported health outcomes. However, qualitative results showed virtual programming helped to foster social connectivity during COVID-19, helped to build a daily routine, and positively impacted mental and physical health.

Conclusion: Shifting to virtual programming in the face of the pandemic enabled us to deliver effective programs affording our community the opportunity to stay physically active and socially connected despite the quarantine orders.

Keywords: older adults, self-management, education, virtual, musculoskeletal health, exercise

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INTRODUCTION

Musculoskeletal conditions are the most common cause of work-related disability among US adults (1). In the United States alone, 54.4 million adults have been diagnosed with arthritis (2). This problem increases with age—as nearly three out of four adults 65 years old and older are affected by musculoskeletal disease, the need to keep older adults active and informed is ever more present (3).

When COVID-19, the disease caused by the novel coronavirus (SARS-CoV-2), began escalating in New York City in March 2020, we knew there would be serious disruption to our community, as it includes a significant number of older adults. This was especially unfortunate because, although this population faces greater health risks due to COVID-19, they are also more affected by the negative consequences of a sedentary lifestyle (4).

Unable to leave home safely, cut off from friends, family, and support networks—the conditions surrounding the pandemic are an anathema to the health concerns of older adults, who require physical activity to maintain their mobility, independence, mental health, and well-being. In addition to a decline in musculoskeletal function, a sedentary lifestyle in older adults has been associated with high blood pressure, elevated cholesterol, cardiovascular disease, type II diabetes, and cancer as well as an increased risk of premature death (5–8). In comparison, Daskalopoulou and colleagues found that "higher levels of physical activity increase the odds of healthy aging by 39% (9)."

The physical changes and life transitions that present with age make older adults more vulnerable to social isolation (10), which has been identified with increased all-cause mortality as well as decreased cognitive function (11–13). This is a substantial public health issue, but one that can be at least partly addressed with the use of technology. However, many older adults face barriers to adapting to new technology (14). They may lack knowledge, confidence, or want additional guidance (15, 16). Others may be concerned about security and reliability (17). Yet research has shown these perceived limitations can be addressed with training (14–16). And, in fact, in a series of focus groups that included 113 older adults, Mitzner and colleagues found that positive attitudes about technology outnumbered negative attitudes (17).

The Public and Patient Education Department (PPED), part of the Education Institute at Hospital for Special Surgery (HSS), a large academic medical center specializing in musculoskeletal health, is committed to improving the health needs of culturally diverse communities, LGBTQ+ individuals, children, adults, and older adults who suffer from or are at risk of musculoskeletal and rheumatologic conditions. When the pandemic forced PPED to cancel onsite programming, we knew it would be essential to move access online and support our community through the transition, particularly those who relied on our institution's exercise and educational programming prior to COVID-19. This case study provides an overview of our experience and best practices developed during our initial shift from onsite programming to a virtual format, supporting and addressing the needs of older adults. This shift, reported herein, spanned from April to August 2020.

CONTEXT

PPED runs a robust program of lectures\workshops, exercise classes, community outreach programs, support groups, and mind-body programs that have traditionally been attended primarily by residents of New York City and the Tri-state area. The focus of these initiatives is to help participants improve self-management of musculoskeletal health and thus improve quality of life.

Although virtual learning has become increasingly popular, in 2019, only 1% of our programming took place online. With over 3,900 community members participating in our programming, the majority (89.5%) were 60 years old or older (**Table 1**). Our engagement with older adults became even more urgent as the shut-down put more people at risk of negative health consequences from isolation and sedentary lifestyles—threats that are especially dangerous to the older adult population (6, 18). Our goal was to continue supporting our community by providing education and exercise to foster physical activity and socialization.

With the shutdown, we had to decide which on-site programs we could move to a virtual setting and how best to do so. This

TABLE 1 | Comparison of Participant Demographics in 2019 and 2020[a].

	2019 (%) *N* = 654	2020 (%) *N* = 336
Gender		
Female	78.4	88.0
Male	21.6	12.0
Age (years)		
Under 20	0.0	0.7
20–29	0.2	1.8
30–39	2.6	3.6
40–49	1.5	8.7
50–59	6.3	12.7
60–69	21.6	33.7
70–79	46.3	30.8
80–89	20.3	7.2
90+	1.3	0.7
Race[b]		
Black or African American	8.5	4.9
American Indian or Alaska Native	2.4	1.1
Asian	6.5	11.6
White/ Caucasian	77.1	81.3
Hawaiian or Pacific Islander	0.2	0.4
Other	8.0	1.9
Ethnicity		
Hispanic/Latino	46.1	7.0
Non-Hispanic/Latino	53.9	93.0
Musculoskeletal Conditions[b]		
Osteoarthritis	53.7	65.0
Rheumatoid Arthritis	14.7	10.9
Osteoporosis	49.4	39.9
Gout	3.5	2.2
Fibromyalgia	2.3	3.8
Other	23.6	27.9

[a] *Data reflects participants from April-August of each year.*
[b] *Does not sum to 100% due to multiple responses.*

transition needed to occur quickly, as many people had already enrolled in our programs. When that was accomplished, we were able to determine which additional needs we could address with programming during the pandemic. In response to the disruption to many aspects of daily living, along with access to health care services, we created short, on-demand videos. Finally, we pivoted to online evaluation of our programming, increasing our qualitative assessment efforts to ensure feedback from as many participants as possible.

Programmatic Elements

During the first 5 months of the pandemic, we shifted 79% of our exercise and educational programming from on-site to virtual access. Safety and ability to deliver program content virtually were the primary reasons why we did not transition 100% of our scheduled programs to an online format.

Exercise Classes

Our exercise program consisted of five exercise classes (yoga, Yogalates™, Pilates, tai chi, and Dance for Fun and Fitness) that were led by certified fitness instructors specialized in working with older adults with musculoskeletal conditions. Each class is comprised of 12–15 participants and runs once a week for 60 min during 6-week increments. As we decided to move our exercise classes to a virtual format, we worked closely with our instructors, taking into consideration the popularity of the onsite class and, most importantly, safety of the exercise conducted without in-person instruction. We also notified participants of the shift by contacting them through email or phone.

Given our desire to provide continuity of services, there was a short turn-around time to start virtual exercise classes. So, we launched an aggressive training plan to ensure that program staff, instructors, and program participants were comfortable with using video conference platforms such as Skype and Zoom. For program staff, one staff member was identified and trained as the master user of Skype and Zoom. Afterward, the master user trained all other program staff and conducted various demonstrations to increase confidence among staff. For instructors, we provided one-on-one trainings and helped them arrange their teaching spaces to enable the best possible vantage point for their virtual studios. For our program participants, we created a four-page instruction guide with screenshots to help them access and navigate Skype, which was our initial platform for virtual classes. However, we found that this process added to participant confusion, with participants' personal computers or devices sometimes appearing different from the screenshots in our guide.

One of our greatest concerns was that older adults might struggle with the new technology, so we focused our attention to support them in this transition. Subsequently, as we transitioned from Skype to Zoom, we eliminated the guides and instead scheduled individualized Zoom "office hours," for anyone who wanted assistance learning how to access the platform and/or to test the connection process. Two staff members were assigned as direct contacts for all class participants, and during off hours, we provided contact information to the Zoom help center. In addition, at the time of the initial transition, these same two program staff were also available during exercise sessions so that classes were not interrupted—one assisted instructors and facilitated the virtual streaming while the other was a direct contact for participants addressing their questions or issues. While there was a definite learning curve, our participants quickly transitioned to the new format and less staff were needed to support the programming.

Lectures/Workshops

Lectures are 60-min didactic sessions taught by physicians, nurses, physical, and occupational therapists and/or nutritionists. Workshops are 60–90 min sessions that offer interactive small group learning experiences covering topics such as good posture and approaches to pain and stress management. Pre-COVID, these programs were held in our New York City conference center or in a meeting space located in one of four Tri-state Outpatient Centers. In April, once the hospital acquired the necessary Zoom licenses, we transitioned onsite lectures to online webinars. The format changed from the academic style podium presentation style using PowerPoint slides that we used for onsite lectures to one that was more appealing for virtual audiences: a panel discussion led by a moderator. Programs were designed to keep participants engaged in the virtual environment and to provide them the same in-person opportunity of submitting their questions. These were live-streamed and recorded, resulting to 24 webinar recordings placed on YouTube for on-demand access. A staff member was also assigned to run the Zoom process and ensure a smooth experience. Given the interactive component of our workshops, we met with the facilitators to adapt the workshops so that they could be delivered safely and effectively in a virtual format.

Support Group

Traditionally, our support group for older adults met onsite once a month in New York City. When the pandemic hit, we increased its frequency to meet weekly but changed the format to conference calls. We also offered mind–body programming using the same method. These programs provided our community with much needed support during a time of isolation. Using conference calls as an alternative to implement programs was critical for us to meet the needs of our older adults as well as our underserved community that did not have a computer, tablet, or smart phone.

Informational Videos

Before COVID-19, we developed occasional videos focused on managing specific musculoskeletal conditions. These videos were heavily produced and took a while to complete. Since the onset of the pandemic, we decided to produce short videos (∼5–6-min long) that could be accessed on demand at our YouTube channel. Over 5 months, we produced 11 of these videos, focused on topics that can help our extended community during a crisis. The only "production" these videos required was a short script from the instructor and a cell phone camera. Upon choosing a topic, we helped instructors develop a script, set their home "stage," and practice delivery. Examples included: stress reduction, meditation for anxiety, and tips for the prevention of

home exercise injuries. Ultimately, these videos provided bite-sized information for the consumer geared towards providing support in a variety of ways.

Community Outreach Programs

Before the pandemic, we brought education and exercise programs to diverse, underserved communities in New York City and CT, serving children, adults and older adults, many with limited English proficiency. This involved partnerships with local organizations and programming often took place at community sites, rather than at one of our facilities. Unfortunately, during the pandemic outreach was limited as many of the organizations we worked with were closed. We did consult with our community partners to determine feasibility of delivering programs *via* Zoom or conference call. Ultimately, in 2020 we were able to set up 13 virtual outreach programs, which was a significantly lower number than the 104 we provided in 2019 (**Table 2**).

Marketing

We expanded our marketing approach to reach a larger audience. Since we shifted our programs to a virtual format, we were able to accommodate a wider reaching community. Expansion included weekly email campaigns marketing our exercise and education programs and monthly paid Google ads marketing our YouTube videos. This is in addition to the traditional methods we used including print publications and social media. Beginning in late March, weekly email campaigns were sent to roughly 1,200 community members sharing health information relevant to the current situation, along the themes of mental health, exercising in quarantine, working from home, nutrition and more. Written in an easy-to-follow and engaging format, these emails also directed readers to additional resources such as our livestream and on-demand programming. Google ads were used to increase awareness of our growing YouTube playlist of short informational videos and webinar recordings.

TABLE 2 | Comparison of number of programs and participants reached by program type in 2019 and 2020[a].

Program Type	2019 (*N*)	2020 (*N*)
Lectures/Workshops		
Programs	32	54
Attendees	1,484	731
Exercise classes		
Programs	140	200
Attendees	830	2,214
Support groups		
Programs	22	41
Attendees	96	372
Community outreach programs		
Programs	104	13
Attendees	1,408	142
Informational Videos		
Videos	9	35
Viewers	113	425,307

[a]*Data reflects participants and programs from April-August of each year.*

Evaluation

Prior to the pandemic, we used a mixed-method approach—quantitative and qualitative strategies to evaluate the impact of our exercise classes. Greater emphasis was placed on our quantitative approach in distributing paper surveys in-person resulting in an average survey response rate of 60–70% per program. However, the change to an online program format necessitated a change to an online evaluation methodology, accomplished through email-administered surveys. But this led to a reduction in our average response rates, which fell to 20–30% per program. As a result of our limited quantitative data, it was critical to understand our community's needs, so we expanded our qualitative evaluation efforts to effectively assess the impact of our classes in its new format.

For quantitative analysis, we assessed demographic information, self-management skills, knowledge gain, program satisfaction, and change in self-reported health outcomes (such as pain intensity, pain interference, physical function, levels of stiffness and fatigue, self-efficacy to overcome barriers to physical activity and physical activity levels). Participants who signed up for 6-week exercise classes were asked to complete pre- and post-online surveys, while those who attended lectures/workshops, support groups, and community outreach programs were asked to only complete post-online surveys (**Figure 1**). Descriptive analyses, paired-sample *t*-tests and McNemar tests were conducted using SPSS 27 at 0.05 level of significance and 95% confidence interval.

For qualitative analysis, we conducted phone interviews and focus groups, and implemented open-ended survey questions to assess participants' experience attending virtual programs, comfort with online learning platforms, willingness to attend in-person programs, and level of satisfaction with the program experience. Demographic information was not collected to protect participant privacy and confidentiality. From a sample of 133 program attendees, 83 were called (**Figure 2**). Of these, 57 did not answer the phone or had an incorrect number on file, 10 declined to participate and 16 consented to a phone interview. Reasons for which program attendees declined to participate were not recorded. We conducted eight focus groups, which had a total of 36 participants. In addition, 46 open-ended questionnaire responses were analyzed from the post-program surveys. Talking scripts were developed and used during semi-structured phone interviews and the focus groups. A specialized qualitative software (Dedoose 8.3.35, Hermosa Beach, California) was used to assign codes, develop categories, and evolving themes. A team of three HSS staff, external to the program, with expertise in qualitative research reviewed transcripts and conducted independent coding to develop validity and reliability of the data, as well as ensure integrity, consistency, and agreement between reviewers. The group discussed differences in code interpretations and developed a set of unifying themes.

IRB approval for human subjects research was obtained.

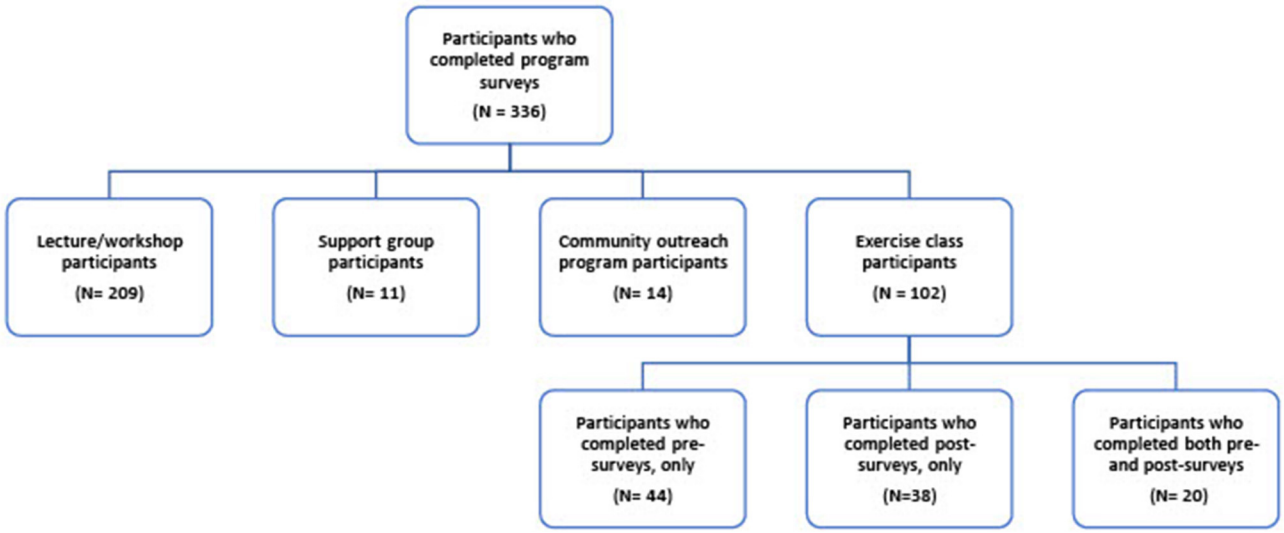

FIGURE 1 | Quantitative survey response flowchart.

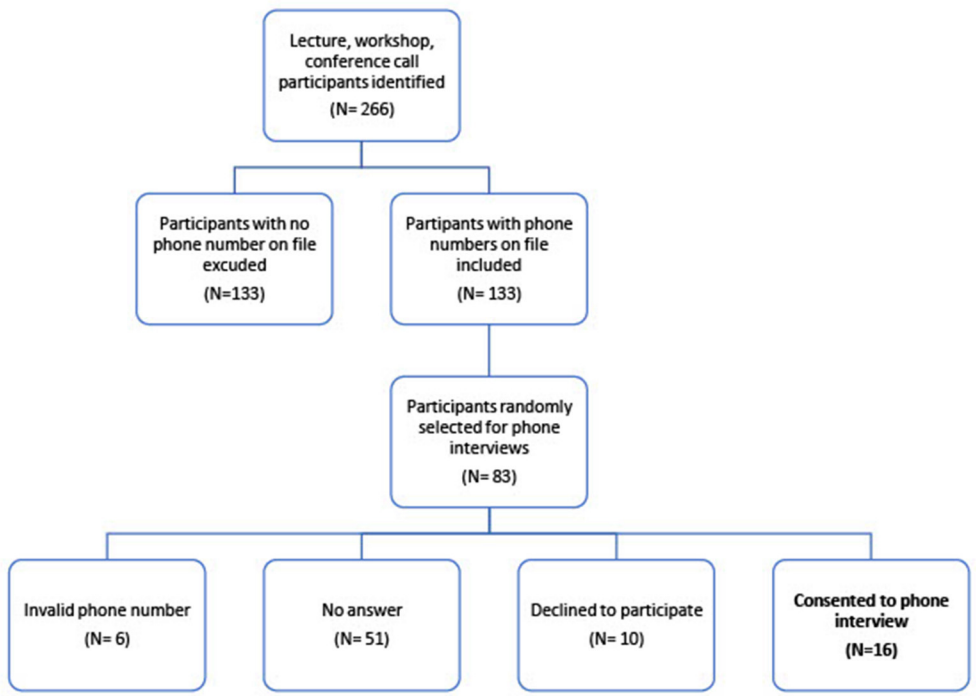

FIGURE 2 | Participant selection for Qualitative Phone Interviews.

Impact of Virtual Programs

Between April and August 2020, we reached 428,766 participants through 343 virtual programs compared to 3,931 participants reached through 307 programs in 2019 of the same time period (**Table 2**). The majority of our participants were women (88%), 60 years and older (72%), and Caucasian (81%), and more than half self-reported that they had been diagnosed with at least one musculoskeletal health condition, i.e., osteoarthritis, osteoporosis, rheumatoid arthritis, gout, or fibromyalgia (**Table 1**). Of the exercise class participants ($N = 20$) who completed both pre- and post-online surveys, the majority were women (100%), 60 years or older (85%), non-Hispanic/Latino (95%), and Caucasian (94%).

Results from online post-surveys ($N = 234$), showed that lectures/workshops, support groups, and community outreach programs were also successful, as 85% of attendees reported that the program had increased their understanding of the topic, 83% reported that the information provided had added to their self-management skills and 90% "agreed" or "strongly agreed" when asked if they were satisfied with the program. Findings from exercise class pre-/post-online surveys ($N = 20$) did not show any significant differences in self-reported outcomes measures such as pain intensity, pain interference, physical function, fatigue and stiffness levels, self-efficacy to overcome barriers to physical activity, and physical activity levels (**Table 3**).

Results from qualitative analysis demonstrated appreciation of virtual programming by participants, as many considered it a wonderful experience and hoped it would continue even after onsite programming resumes. They welcomed the ability to include the addition of routinely scheduled online programs when many of their day-to-day activities were canceled due to COVID-19. They appreciated the opportunity for socialization with other class members and instructors and reported that the interpersonal connection improved their mental health. Although participants were uncomfortable about the safety of in-person classes once onsite programming resumes, many admitted that they had trust in HSS to maintain a safe environment, but not in the public transportation they would use to get there. They valued the convenience of the model and stated that with the assistance of our team, the platforms were easy to use. Participants noted that they would like more flexibility to interact and engage with instructors and classmates; they would also like to access more recordings of exercise classes (**Table 4**).

DISCUSSION

Overall, results show that our programs remained popular with older adults, even when running on a virtual platform. Participants used our exercise classes to maintain physical activity, support mobility, relieve stress, and stay connected. Ultimately 90% of participants reported satisfaction with their experience. Recent studies have found virtual education can be effective in providing older adults with opportunities for exercise and improving pain management skills (19–21). Our research further supports these findings and shows that virtual programming can improve the quality of life of older adults.

The success of our online programming supports the value of this modality in the health education of older adults. *Older*

TABLE 3 | Differences in Outcome Measures Between Pre and Post Intervention ($N = 20$)[a].

Measure	Pre-test	Post-test	*P*-value[b]
Physical Function[c]			
Ability to lift or carry groceries (*n*, %)	13 (65.0)	14 (70.0)	1.000
Ability to climb one flight of stairs (*n*, %)	15 (75.0)	17 (85.0)	0.500
Ability to climb several flights of stairs (*n*, %)	12 (63.2)	13 (68.4)	1.000
Ability to bend, kneel or stoop (*n*, %)	13 (65.0)	14 (70.0)	1.000
Ability to bath or dress yourself (*n*, %)	17 (89.5)	17 (89.5)	1.000
Physical Activity Assessment[d]			
Walking; ≥3 times/week for 30 min (*n*, %)	10 (50.0)	14 (70.0)	0.289
Moderate-intensity PA; ≥3 times/week for 30 min (*n*, %)	9 (47.4)	13 (68.4)	0.344
Vigorous-intensity PA; ≥3 times/week for 20 min (*n*, %)	0 (0.0)	7 (35.0)	-
Stiffness (M, SD)	2.2 (2.1)	1.7 (2.0)	0.268
Fatigue (M, SD)[e]	1.8 (2.2)	1.2 (1.6)	0.131
Self-Efficacy to Overcome Barriers to Physical Activity (M, SD)[f]	7.7 (2.4)	8.0 (2.4)	0.546
Pain Intensity (M, SD)[g]	2.3 (2.7)	1.8 (2.2)	0.523
Pain Interference on aspects of quality of life[h]			
General activity (M, SD)	0.9 (1.8)	0.8 (1.4)	0.691
Mood (M, SD)	0.6 (1.5)	0.8 (1.7)	0.330
Walking ability (M, SD)	1.1 (2.0)	0.8 (1.4)	0.349
Normal work (M, SD)	0.9 (1.8)	0.8 (1.4)	0.772
Relations with other people (M, SD)	0.6 (1.2)	0.5 (1.2)	0.494
Sleep (M, SD)	1.0 (1.9)	1.1 (2.1)	0.578
Enjoyment of life (M, SD)	0.7 (1.7)	0.7 (1.8)	1.000

[a] *Data are reported in mean (M), standard deviation (SD), number, and frequency.*
[b] *Statistical significance is based on McNemar and paired T-Tests statistics.*
[c] *As measured by the physical function items on the SF-36 Health Survey.*
[d] *As measured by the 3-question Physical Activity Questionnaire (3Q).*
[e] *As measured by the Exercise Regularly Scale of the Chronic Disease Self-Efficacy Scales.*
[f] *As measured by the Brief Fatigue Inventory.*
[g] *As measured by the PROMIS Numeric Rating Scale v1.0—Pain Intensity 1a.*
[h] *As measured by the Brief Pain Inventory.*

TABLE 4 | Select Quotes from Participants in PPED Virtual Programming, April—August, 2020.

Major Themes	Participant Feedback
Establishing Routine	"The programs are providing a sense of normalcy and giving some structure to the day."
	"The classes have given structure to my otherwise limited life under quarantine and provided a space for self-nurturing and self-care."
	"It is a regular activity to look forward to while I'm stuck at home."
Interpersonal Connection—Socialization	"The classes have given structure to my otherwise limited life under quarantine and provided a space for self-nurturing and self-care."
	"It is a regular activity to look forward to while I'm stuck at home."
Interpersonal Connection—Mental Health	"Helped to have an enjoyable time with others. Took me 'out of my head' and helped me to regain more optimistic view for the future."
Safety—Not comfortable with in-person	"In terms of going back to [in person] classes, I'm concerned about the cleanliness of the exercise equipment (like blocks and yoga mats, etc.). It's hard to know who else has used it and how well it has been cleaned."
	"I have no desire to be back in a group environment, especially when there is a virtual option available. Why would I take a risk with my health?"
Safety—Trust in HSS	"I don't think it is a matter of holding in-person classes in HSS because I trust HSS to put safety measures in place. It is a matter of how I would get to the classes."
Ease of Virtual Programming—Comfortable with technology	"I am not a computer person. I have a lot of problems with computers. However, HSS made it very easy for me and I had a very good experience."
	"It was organized very well. [The coordinator] introduced [the instructor] and set us up. It took about a week or so to get everyone sorted out and then after that it went very smoothly. I could hear from the other participants and know they were happy too."
Ease of Virtual Programming—Convenience of programs	"It has given me the opportunity to exercise when circumstances prevent me from going outdoors."
	"It has helped me keep a regular schedule for exercising and has encouraged me to practice Tai Chi Chih on my own at home."
More Dynamic Content Delivery—Increase interaction and engagement	"Online is not the same as in person….I miss [the instructor] telling us what we're doing incorrectly."
	"When the support group is in-person we can have personal conversation after the group, but you can't do this when we are not in person."
	"I think the program is good; but the class is only 1 h and could be extended for 5 min either before or after so you have a chance to ask questions. When you attend in person classes you have the opportunity to ask questions before or after the class."
Appreciative of Programs—Positive Experience	"The fact that they exist is wonderful. I'm learning things that I haven't done before. I was poised to do Pilates before the pandemic so I found this to be an interesting way to extend into a new practice. It is an easy way to try something new or to do something that you've already been doing."
Appreciative of Programs—Continuing Virtual Programs	"I hope it doesn't disappear because it is convenient—It has value and it will continue to have value when we go back to in-person."
	"I would hope that when the city and state allow in-person classes the zoom classes be offered as something complementary to the in-person classes."

Americans 2020 reported that as people age, they spend less time socializing and being active. In fact, in 2018, only 14% of people age 65 and over met recommended guidelines on physical activity (22). Our research shows that with attention and flexibility, most older adults can become comfortable using online platforms. They can derive significant benefit from the ability to attend a workshop on posture or participate in a yoga class from the safety of their own homes. Furthermore, virtual programming enables older adults to access advice from the top experts on any topic from anywhere in the world.

In dealing with the demands of the situation, we learned to quickly adapt, prioritize, and move forward. We had been working on increasing our online presence, and the details of each step were meticulously planned and addressed. However, with the shutdown, our team needed to learn quickly and pivot when change was necessary. Due to the unique differences in our programs, we customized our approach to transitioning for each program by assessing the needs of our instructors/speakers and participants and identifying challenges and/or potential barriers. As we became more adept at delivering virtual programming, we worked toward extending the reach of our programs beyond our existing audience. Within 5 months, we achieved a 10,807% increase in program reach with participants from around the world accessing our virtual programs and our curated library of YouTube content. We plan to continue building on-demand content for YouTube after we return to in-person programming and continue offering many of our programs in a virtual format.

Lessons Learned and Practical Implications

Throughout the process of switching to virtual formatting, we developed best practices and learned valuable lessons.

Exercise Classes

By offering classes online, we were able to expand our community far beyond the previous limits of New York City and its surrounding areas. Our most important consideration was to decide which classes could be offered virtually without risk to the participants (i.e., falls). However, it was also essential to work with all constituents and ensure that they are prepared and comfortable with the change in format through trainings. Ultimately, most participants found it easy and convenient. However, through evaluations, we learned that some participants wanted more time to socialize with other participants and instructors.

Lectures/Workshops

The first critical change was to revise the format of our onsite lectures to panel-driven interactive webinars to keep the audience engaged. Including a moderator helped to foster interactivity. We also developed topics that were grounded in the basics of musculoskeletal health but tailored for the particular moment. For example, one webinar discussed telehealth for musculoskeletal needs and another addressed ergonomics while working from home. We found it important to get the professional perspective of panelists from the beginning stages of program development. In planning, for example, they were best prepared to advise whether slides would be helpful or if a topic might be best addressed with a moderated discussion. We increased our reach by recording the programs and posting them on YouTube.

Finally, attendance was an issue. Before the COVID-19 shutdown, more than 50% of those who preregistered attended onsite lectures. While we saw higher registration numbers for our online programming, attendance rates dropped to roughly 30%. More research is needed to understand why attendance rates dropped. Overall, some people continued to have trouble with Zoom; some chose not to join by video and preferred to call into the Zoom number. Ultimately, we still had to offer some programs *via* conference call, specifically our support group for older adults and our mind–body workshops to manage pain and stress.

Community Outreach Programs

In navigating the circumstances with our community partners, we did our best to remain flexible—for example, being willing to use conference calls to deliver content. We also found it wise to plan for programs lasting a little longer than scheduled, as it often took some time to establish virtual or phone connection with community members.

Informational Videos

Videos were a significant part of our success in increasing viewership and reaching a large number of our community members; this was helped by paid advertising (i.e., Google ads). By the end of 2020, we achieved over 1.5 million viewers of our on-demand YouTube content. However, delivering appealing content was also key to our reach. One limitation was the inability to get demographic information from our YouTube viewers.

Evaluation

The move to online programming affected our survey response rates for exercise classes, with only 20 participants completing both pre- and post-online surveys. The small sample size was a limitation resulting in the inability to detect an effect and the magnitude of the effect. However, this limitation was addressed by enhancing our qualitative efforts to provide relevant and impactful data. There is a need to further explore effective online evaluation strategies to improve survey response rates and to engage in ongoing process improvement of program evaluation activities. Also, while we hoped to recruit a group with good racial and gender diversity, most of the participants were Caucasian women. We will continue to explore ways to improve diversity of participants.

CONCLUSION

In the face of the pandemic, the ability to quickly move our programming to a virtual platform enabled PPED to deliver programs that enabled at-risk older adults to virtually participate in community education programs and exercise classes, despite quarantine orders. Our virtual programs aided in promoting musculoskeletal health, physical activity, and social connectedness, from the safety and comfort of participants' homes. Nonetheless, there is a need to further explore opportunities for additional socialization in online programming. Overall, this experience has shown that with careful planning, a shift in program delivery for older adults can be successful when accounting for perceived barriers to participation; and when programs are tailored to the specific needs (i.e., health, technology, access) of our community.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by HSS Institutional Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

PS-V, CZ, MW, LR, BT, BM, RW, TO, SG, and LR made substantial conceptual or design contributions or gathered and analyzed important data. PS-V, CZ, BT, TO, and SG either helped draft or critically revise the paper in keeping with important intellectual content. PS-V, CZ, MW, LR, BT, BM, RW, TO, SG, and LR provided final approval before publishing. PS-V, CZ, MW, LR, BT, BM, RW, TO, SG, and LR agreed to be accountable for the accuracy of the work. All authors contributed to the article and approved the submitted version.

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Does the Internet Use Improve the Mental Health of Chinese Older Adults?

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Purpose: The Internet has become an important part of daily life. However, older adults in China remain digital refugees amid the rapid development of digital information technology. This study attempts to scientifically answer how Internet use affects the subjective welfare of older adults.

Method: Using data from the 2014 and 2016 China Longitudinal Aging Social Survey (CLASS), a combination of ordinary least squares, ordered logit regression models, and propensity score matching (PSM) models were used to analyze the effects of Internet use on the mental health of Chinese older adults.

Results: Our findings suggest that Internet use affects the mental health of older adults and increases the incidence of their depressive symptoms. These findings are robust to changing the key indicators, research method, and sample. Further heterogeneity analysis reveals that the negative effects on mental health are more evident for specific groups of older adults, such as those who are women, younger and middle-aged, high-income, non-rural Hukou, less educated, and living with others.

Conclusions: Cultivating the ability of older adults to use the Internet and maintain a rational attitude while doing so can prevent its negative impact on their life satisfaction. Moreover, it can improve their attitudes toward using the technology and reduce their anxiety.

Keywords: internet use, older adults, mental health, depression, China

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INTRODUCTION

Since the 1990s, the Internet and other information technologies have rapidly developed in China. The number of Internet users in China reached 940 million in June 2020, and the proportion of users aged 60 and above is increasing from 6.7% in March 2020 to 10.3% now (1). Meanwhile, the aging population of China is growing rapidly. It is predicted that the share of the population over 60 years old in China will reach 34.9% by 2050, by which time China will enter a stage of deep aging (2). How to deal with this accelerating aging and the increasing number of the older population is not only the focus of discussions in academia and the government but also a topic of concern in all sectors of society (3).

In this context, mental health issues, such as loneliness and depression, are receiving increasing attention, but their relationship with Internet use is uncertain. Internet use has enhanced the

mental health of older adults by expanding the scope of their social interactions, enriching their life experiences, and increasing the frequency of contact with family, friends, and other social network members (4). The openness, anonymity, virtualization, and equality potential of the Internet promote social participation in current affairs. Internet use also promotes social and community participation among older adults and improves their level of social adjustment. This in turn enhances their psychological well-being (3, 5–8), especially for those who are withdrawn and less socially engaged (9, 10). Online chatting can reduce loneliness and decrease the likelihood of depression in older adults. Using data from the Health and Retirement Survey (HRS) in the United States from 2002 to 2008, Cotten et al. (7) found that older adults were 33% less likely to be depressed when using the Internet. Khalaila and Vitman-Schorr (11) found that Internet use can improve their quality of life directly or indirectly by reducing loneliness, with the indirect effect influenced by ethnicity and the direct effect influenced by the amount of time older adults spend with their families. Using data from the 2008 U.S. Health and Retirement Study, Heo et al. (12) found that Internet use reduced loneliness in older adults by enhancing their social support as a mediating variable, which in turn enhanced their life satisfaction and psychological well-being, with the help of structural equation modeling. A recent study by Haase et al. (13) has suggested that older adults can mitigate the psychological effects of social isolation through virtual socialization during a new crown epidemic.

Studies of older adults with mobility impairments found that the Internet plays an important role in increasing interpersonal communication, maintaining family bonds, and expanding social networks (9, 14–16). However, overindulgence, undesirable Internet behaviors, and the spread of negative information and emotions may reduce the social participation of older adults, causing loneliness, and negatively affecting their mental health (17–21). The Internet time substitution hypothesis suggests that using the Internet reduces time and opportunities for offline social interactions, resulting in more self-isolation, which is detrimental to the expression of emotions and social relationships (22). In severe cases, excessive Internet use may even induce psychological disorders such as depression (22). This is in line with the technological stress theory that excessive use of the Internet can lead to health deterioration due to addiction (20, 21, 23, 24). Both Internet addiction or overuse and dependence on online social media increase the health risks of users (23). In addition, Internet use increases social comparison for relative income levels and social status, which plays a decisive role in the well-being of an individual (25–28). The spread of the Internet can increase access of older adults to information, constantly raising the upper limit of the material needs of people, making it easier to compare themselves online with people from any country and background. Social climbing behavior based on this can bring about a sense of psychological loss and relative deprivation (29–31). Further, the information depression theory argues that access of people to a large number of negative news reports *via* the Internet can reduce their enthusiasm for political participation and lead to a continued decline in social trust, which negatively affects their mental health (32).

From the above literature review, it can be seen that while scholars around the world have researched the relationship between Internet use and the mental health of older adults, this topic has not yet attracted widespread attention from scholars in China. Moreover, whether the above conclusions are applicable in the Chinese context requires further discussion. Previous studies have mostly focused on one dimension (e.g., rural or urban), one region, or small samples, limiting the robustness of the findings. In terms of research methods, most studies were conducted using ordinary least squares, Oprobit, and logit models, with less attention paid to endogenous issues. This means the results might be biased due to omitted variables and self-selection issues. For example, older adults with good health may be more willing to learn and use the Internet, which may affect the reliability of the findings.

This paper examines the following questions: What kind of impact does Internet use have on older adults? Can it help them improve their mental health and cope with depression? Considering the variability in the demographics of older adults, are there differences in the impact of Internet use on their mental health? The answers to the above questions can better clarify the relationship between Internet use and depression among older adults. Moreover, they can enhance the well-being of older adults and promote sustainable economic and social development, while ensuring the achievement of the Two Centenary Goals.

Our study examined the relationship between Internet use and mental health among older adults in China, based on data from the 2014 and 2016 China Longitudinal Aging Social Survey (CLASS). We used propensity score matching (PSM) to solve the above endogeneity problem while making the findings more internally valid by replacing the indicators, the study sample, and using difference-in-difference (DID) for robustness testing. On this basis, while considering the differences in older adult groups, a heterogeneity analysis was conducted by gender, age, Hukou, income level, education level, and the number of companions, to analyze the differences in the effects of Internet use among older adults.

This study makes the following contributions. First, it systematically compiled the research results on the impact of Internet use on the mental health of older adults, explored the relationship between Internet use and mental health among older adults in China based on CLASS data, and sought to confirm the applicability of existing studies to the Chinese sample. This makes the current study more externally valid. Second, in contrast to previous studies, we used the PSM model to examine the effects of Internet use on mental health and further ensured the internal validity of the findings by changing indicators and samples and using DID models. Third, based on existing research, this study compared differences in the mental health of different groups of older adults to further clarify the relationship between Internet use and depression among older adults in order to provide a realistic basis for better guidance on using the Internet to enhance the mental health of older adults. Finally, in response to the research findings and the actual situation, we make relevant policy recommendations, which may present an important reference for countries around the world in regulating Internet use.

The remainder of this paper proceeds as follows. Section Methods introduces data sources, variable selection, and the setting of the econometric model. Section Results focuses on the discussion of the research results, using the PSM method to study the relationship between Internet use and mental health among older adults and conducting a robustness analysis. Section Discussion shows a heterogeneity analysis to discuss the differences in the effects of Internet use on mental health among different groups of older adults. Section Conclusion concludes and presents the policy recommendations.

METHODS

Data

The data used in the present study come from the CLASS, a nationally representative and longitudinal survey of Chinese aged 60 and above. CLASS is a nationwide, continuous, and large-scale social survey project whose objective is to regularly collect data on the social and economic background of the older adult population of China to understand the various problems and challenges they face in the process of aging, access the actual effects of various social policy measures in improving the quality of life of older adults and provide an important theoretical and factual basis for solving aging problems in China. This survey used a multistage sampling method. County-level units within provinces were selected as the primary sampling units (PSUs). A community or village was selected as the secondary sampling unit (SSU), and the final sampling unit was household. PSUs were randomly selected using a proportionate-to-population size sampling technique from a sampling frame containing all county-level units. The selection of SSUs followed the sample procedures as PSUs, and the ratio of urban to rural relevant population size was set at 6:4. People aged 60 years and above were randomly selected from each SSU based on a sampling map. The CLASS conducted its first nationwide survey in 2014 and two follow-up surveys in 2016 and 2018. Given that data from the 2018 wave have not yet been released, we only used data from the years 2014 and 2016.

The original sample size of the 2014 CLASS data was 11,511, with detailed information collected on key indicators of basic status, physical health, social participation, and social support of older adults. The final sample of 476 villages/neighborhoods in 134 counties corresponded to 28 out of 31 provinces (or municipalities) in China (CLASS webpage 1). After screening for variables and removing missing values, 7,040 respondents from 28 provinces presented sufficient data for the analysis. The 2016 CLASS data were based on a follow-up survey conducted on the 2014 data, successfully tracking 6,603 people, with a 57.4% follow-up rate, and after supplementing the sample with 4,892 people, the final sample size was 11,471 people. In addition, for the first time in 2016, CLASS included a survey on Internet use among older adults, which comprehensively measured key indicators affecting the lives of older adults. After variable screening and data cleaning, the final sample size of the regression model in this study was 6,972.

Variables

Dependent Variable

Mental health was the dependent variable for this paper, referred to in CLASS as depressive tendencies. In the CLASS questionnaire, depression scores were calculated using the Depressive Tendency Scale (DTS), a simplified version of the CES-D scale, with nine questions covering aspects of daily mood, loneliness, sleep, sufficiency, and life status of older adults. Each question has three answers, "not," "sometimes," and "often," with values of 1, 2, and 3, respectively. The scores of the nine questions are summed up and scored on a scale of 9–27, with higher scores indicating more severe depressive tendencies. Jin and Zhao (3) summed up the nine questions and used the higher score as a criterion for depressive tendencies; however, He et al. (33) found that the flow center depression scale (nine-question Chinese short version), with the reliability and validity of 17 points as the cutoff for distinguishing high risk of depression, was better. Therefore, in this study, we used two ranges, 9–17 and 18–27, and assigned the depressive tendency variable as 0 and 1, with 0 representing a low depressive tendency and 1 representing high depressive tendency. Based on a comprehensive evaluation of the multidimensional life of surveyed individuals, Ma (32) points out that life satisfaction is a stable measure of the long-term well-being of people. In the CLASS questionnaire, life satisfaction was divided into five levels, corresponding to values 1 (very satisfied) to 5 (very dissatisfied).

Independent Variable

The independent variable in this study was Internet use (*net)*. Referring to the study by Jin and Zhao (3), it was set as a dichotomous variable based on the CLASS question, "Do you often use the Internet now?" Moreover, given the prevalence of smartphone use today, smartphone use (*smart*) was regarded as a proxy variable of Internet use. The variable obtained from the question, "Do you currently use a smartphone?," with a value of 1 for smartphone use and 0 for no smartphone use.

Covariates

Considering the influence of other factors on the mental health of older adults, gender, age, marriage, education, nation, religious belief (*religious*), Hukou, number of companions (*com_num*), income, whether they receive pension insurance (*pension*), level of community services (*com_s*), social support (*soc_s*), willingness to participate in society *(soc_p*), and number of children (*cld_num*) were used as covariates in the regression model. The results are shown in **Table 1**.

Model

The research question in this paper concerns the impact of Internet use on the mental health of older adults. However, Internet use by older adults is not random and may be subject to selective bias. If we simply use regression analysis, the estimates obtained may be biased. Therefore, we used the PSM method, which is an analytical method based on the counterfactual inference framework model proposed by Rosenbaum and Rubin in 1983 that can effectively address the problem of endogeneity. The basic idea is to compress the information collected from the

multisample survey through logit regression or probit methods to produce a propensity score, and then match the treatment and control groups in the sample based on the propensity score to calculate the average treatment effect on the treated (hereafter referred to as ATT). In this study, ATT on the mental health of older adults was estimated by matching groups of older adults according to whether they use the Internet. In this study, the dummy variable $D_i = \{0, 1\}$ is used to indicate whether older adults use the Internet, where 1 is the treatment group, representing older adults who use the Internet, and 0 is the control group, representing those who do not. The index of the extent to which mental health of older adults is affected by Internet use is expressed as y_i. The treatment effect of D_i on y_i is:

$$y_i = \begin{cases} y_{1i} \; D_i = 1 \\ y_{0i} \; D_i = 0 \end{cases} \tag{1}$$

where y_{1i} denotes the mental health of older adults who use the Internet, and y_{0i} denotes the mental health of those who do not. The treatment effect of Internet use on the mental health of older adults is

$$y_i = (1 - D_i)\, y_{0i} + D_i y_{1i} = y_{0i} + \left(y_{1i} - y_{0i}\right) D_i \tag{2}$$

The average treatment effect for participants is.

$$\begin{aligned} ATT \; &= \; E\left[y_{1i} - y_{0i} | D_i = 1, P(X)\right] = E\left[y_{1i} | D_i = 1, P(X)\right] \\ &- \; E\left[y_{0i} | D_i = 1, P(X)\right] \end{aligned} \tag{3}$$

RESULTS

Statistical Description of Variables

Table 2 shows the descriptive statistics of each variable, which are divided into three parts: the total sample, the treatment group (using the Internet), and the control group (not using the Internet). Their means and standard deviations were counted separately. As shown in **Table 2**, overall, only 11.3% of the total sample of older adults uses the Internet, while the relative proportion of older adults using smartphones is a little higher, reaching 17.5%. This shows that Internet use among older adults in China is still relatively low. In addition, the overall depressive tendency and life satisfaction of older adults in China were 0.273 and 2.157, respectively. Their mental health was good and life satisfaction was also at a relatively satisfactory level. To visually compare the differences in variables such as propensity to depression between Internet users and non-users, the statistics are presented separately in this paper. As shown in **Table 2**, the difference is 0.071 in depressive tendencies between Internet users and non-users, with Internet users having a higher depressive tendency index and poorer mental health. However, in terms of well-being in life, the sample group using the Internet was 0.285 lower than that of non-users and had a relatively lower sense of well-being. From the description of the variables, it can be intuitively seen that there are large differences between Internet users and non-users in terms of age, level of education, type of Hukou, income level, etc. Internet users are 3 years younger than non-users, but their level of education is 0.369 years higher and their income level is almost 16,000 RMB higher than non-users. These findings provide a basis for future research.

Baseline Regression Results

In this study, the treatment group (using the Internet) and the control group (not using the Internet) were used for PSM, and three matching methods were used: k-nearest neighbor matching, radius matching, and kernel matching. The results are shown in **Table 3**, with a mean treatment effect of 0.081 before matching; the results were significant at the 1% level. This indicates that, without controlling any variables, using the Internet increases the propensity of older adults to depression by 8.1%. In K-nearest neighbor matching, the depressive tendency was around 0.081 higher among older adults who used the Internet compared to those who did not, and the result was significant at the 1% level. To determine the accuracy of the results, the data were matched using both radius matching and kernel matching, and the average treatment effects obtained from matching were similar and significant at the 1% level.

To measure the balance between older adults who use the Internet and those who do not, that is, to observe whether there is a significant difference in the distribution of matching variables between the matching samples, we conducted a balance test on the PSM results. As shown in **Table 4**, the deviation proportion of all matching variables after matching decreased compared with that before matching, and the absolute error value of other variables decreased by more than 70%, except for some variables such as religious beliefs and community support. As the *t*-test results show, the hypothesis that the difference in matching variables between the two sample groups is zero cannot be rejected, which indicates that PSM greatly reduces the difference between the two samples of older adults, passing the balance test.

This study also reports the kernel density map before and after matching, as shown in **Figure 1**. After matching, the coincidence degree of the two curves in the treatment and control groups significantly improved.

In the CLASS questionnaire, a question on whether older adults use smartphones was included. Jin and Zhao (3) considered that the proportion of Internet users using mobile phones to access the Internet reached 99.1%. Therefore, the use of smartphones was regarded as an alternative variable of Internet use. Combined with the statistical data of this study, the number of older adults who use smartphones was 6% higher than those who use the Internet. Therefore, it was more representative to select smartphone use as an alternative variable to Internet use in this study for robustness tests. The regression results are shown in **Table 5**. Before matching, the average processing effect was 0.063, which was significant at the 1% level. Older adults using smartphones showed an increased depressive tendency and a worse mental health status. After matching, the average treatment effect was approximately 0.067, which was significant at the 1% level. Compared to before matching, the change in life satisfaction was small, but the results still showed that the use

TABLE 1 | Descriptive univariate information for variables.

Variables	Descriptive univariate information
Dependent variables	
Mental health	Low depressive tendency = 0, high depressive tendency = 1
Life satisfaction	Very satisfied=1, relatively satisfied=2, average=3, relatively dissatisfied=4, very dissatisfied=5
Independent variables	
Net	Internet use, using the Internet = 1, not using the Internet = 0
Smartphone	Smartphone use, yes = 1, no = 0
Covariates	
Gender	Male = 1, Female = 0
Age	Age of respondents
Marriage	Married with spouse = 1, other = 0
Education	Primary school and below = 0, junior school and above = 1
Nation	Han Chinese = 1, minority nation = 0
Religious	Religiously affiliated = 1, Not religiously affiliated = 0
Hukou	Rural = 1, non-rural = 0
Com_num	Number of people living permanently with the respondent
Health	Level of physical health, Very healthy = 1, relatively healthy = 2, average = 3, relatively unhealthy = 4, very unhealthy = 5
Soc_p	Willingness to participate in society; the higher the value, the stronger the willingness to participate in society
Income	Annual income of respondents
Pension	Receiving basic pension insurance = 1, not receiving basic pension insurance = 0
Com_s	Level of community services, the lower the value, the higher the level of community service
Soc_s	Social support, the higher the value, the higher the level of social support
Cld_num	Number of living children

TABLE 2 | Descriptive statistics of the main variables.

Variables	Total sample (*N* = 69,72)		Using the internet (*N* = 791)		Not using the internet (*N* = 6,181)	
	Mean	***Sd***	***Mean***	***Sd***	***Mean***	***Sd***
Mental health	0.273	0.446	0.345	0.476	0.264	0.441
Life satisfaction	2.157	0.797	1.918	0.630	2.187	0.811
Net	0.113	0.317	1	0	0	0
Smartphone	0.175	0.380	0.891	0.311	0.0836	0.277
Gender	0.511	0.500	0.496	0.500	0.513	0.500
Age	70.26	7.544	67.04	6.786	70.67	7.538
Marriage	0.714	0.452	0.794	0.405	0.703	0.457
Education	0.338	0.473	0.665	0.472	0.296	0.457
Nation	0.752	0.432	0.824	0.381	0.742	0.437
Religious	0.0818	0.274	0.0973	0.297	0.0798	0.271
Hukou	0.442	0.497	0.119	0.324	0.484	0.500
Com_num	2.660	1.262	2.692	1.203	2.656	1.270
Health	2.638	0.937	2.255	0.860	2.687	0.936
Income	22405	59480	36629	31511	20584	61923
Pension	0.767	0.423	0.866	0.341	0.754	0.431
Com_s	17.87	0.664	17.77	0.876	17.89	0.630
Soc_s	14.31	5.549	14.03	5.619	14.34	5.540
Soc_p	22.58	7.420	25.28	5.060	22.23	7.601
Cld_num	2.492	1.391	1.777	1.117	2.584	1.396

TABLE 3 | Propensity score matching (PSM) estimation for effect of Internet use on mental health.

Matching method	Sample	Using the internet	Not using the internet	ATT	S.E.
K-nearest neighbor ($n = 4$)	Before matching	0.345	0.264	0.081***	0.017
	After matching	0.345	0.364	0.081***	0.022
Radius matching	Before matching	0.345	0.264	0.081***	0.017
	After matching	0.345	0.270	0.075***	0.020
Kernel	Before matching	0.345	0.264	0.081***	0.017
	After matching	0.345	0.270	0.075***	0.020

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; Standard errors after matching were obtained by the bootstrap method, and the number of self-help samples is 500.*

TABLE 4 | Covariates balance testing for propensity score matching.

Variables	Before matching	Mean value		Deviation%	Deviation reduction ratio%	*T*-test	
	After matching	Using the Internet	Not using the Internet			*T*-value	*P* > |*t*|
Gender	U	0.496	0.513	−3.400	3.100	−0.900	0.369
	M	0.496	0.512	−3.300		−0.650	0.514
Age	U	67.04	70.67	−50.70	97.20	−12.90	0
	M	67.04	67.14	−1.400		−0.310	0.759
Marriage	U	0.794	0.703	21	84.60	5.310	0
	M	0.794	0.808	−3.200		−0.690	0.489
Education	U	0.665	0.296	79.40	98.60	21.31	0
	M	0.665	0.670	−1.100		−0.210	0.831
Nation	U	0.824	0.742	20	89.20	5.020	0
	M	0.824	0.833	−2.200		−0.470	0.641
Religious	U	0.0974	0.0798	6.200	−15	1.700	0.0890
	M	0.0974	0.0771	7.100		1.430	0.154
Hukou	U	0.119	0.484	−86.60	99.70	−20	0
	M	0.119	0.118	0.300		0.080	0.938
Com_num	U	2.692	2.656	2.900	43.50	0.750	0.453
	M	2.692	2.712	−1.600		−0.330	0.744
Health	U	2.255	2.687	−48	97.10	−12.31	0
	M	2.255	2.243	1.400		0.300	0.765
Income	U	36,629	20,584	32.70	92.30	7.170	0
	M	36,629	35,394	2.500		0.270	0.784
Pension	U	0.866	0.754	28.80	86.40	7.020	0
	M	0.866	0.851	3.900		0.870	0.387
Com_s	U	17.77	17.89	−14.70	75.10	−4.470	0
	M	17.77	17.80	−3.600		−0.600	0.546
Soc_s	U	14.03	14.34	−5.600	58.20	−1.490	0.137
	M	14.03	13.90	2.300		0.470	0.640
Soc_p	U	25.28	22.23	47.20	97	10.98	0
	M	25.28	25.38	−1.400		−0.350	0.729
Cld_num	U	1.778	2.584	−63.80	99.40	−15.62	0
	M	1.778	1.772	0.400		0.090	0.925

of smartphones has a negative impact on the mental health of older adults.

To reduce the impact of endogenous problems and avoid reverse causality as much as possible, we used the DID method to analyze the impact of Internet use on the mental health of older adults. Based on the CLASS data from 2014 to 2016 for analysis, the data of 2014 were treated as before Internet use and 2016 as after. It should be noted that in the DID model, we assigned a value of 0 for depressive tendencies and 1 for non-depressive tendencies. **Table 6** presents the descriptive statistics of the variables.

The results of the DID method are shown in **Table 7**. Before using the Internet, the difference between the experimental and control groups was 0.016. After using the Internet, the difference

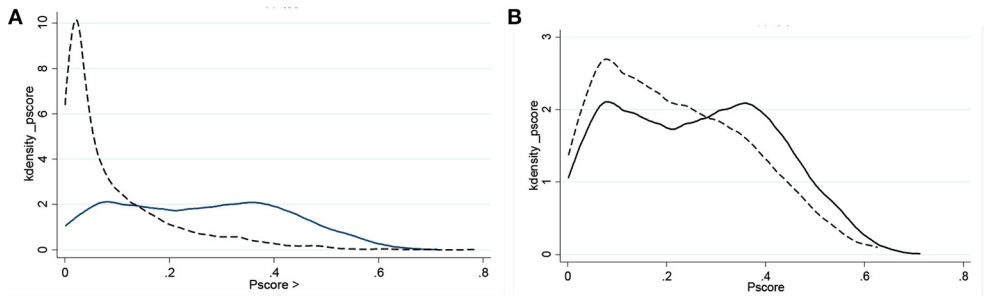

FIGURE 1 | Kernel density maps: **(A)** before matching; **(B)** after matching. Using the internet—Not using the internet.

TABLE 5 | Propensity score matching estimation for effect of smartphone use on mental health.

Matching method	Sample	Using the internet	Not using the internet	ATT	S.E.
K-nearest	Before matching	0.325	0.262	0.063***	0.014
neighbor ($n = 4$)	After matching	0.324	0.257	0.067***	0.018
Radius matching	Before matching	0.325	0.262	0.063***	0.014
	After matching	0.324	0.260	0.065***	0.017
Kernel	Before matching	0.325	0.262	0.063***	0.014
	After matching	0.324	0.260	0.065***	0.017

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$; Standard errors after matching were obtained by the bootstrap method, and the number of self-help samples is 500.

between the experimental and control groups was 0.082. The final DID result was −0.099, which was significant at the 5% level. This means that the average depression tendency of Internet users increased by 0.099 and their mental health status decreased, which is consistent with previous results.

To further verify the robustness of the results, we used the 2017 Chinese General Social Survey (CGSS) data to re-estimate. There were 12,582 original samples from the data. After deleting missing values, the sample size used in this study was 4,225. We also employed the PSM method. The question "How often have you felt depressed or were depressed in the past 4 weeks" replaced the depression tendency variable in this paper as the independent variable. The answers to the question were "always," "often," "sometimes," "rarely," and "never," with values of 1 to 5, respectively. The higher the value, the better the mental state and lower the depressive tendency. According to the CGSS 2017 questionnaire, the question "Have you ever been online in the past six months, including using computers, mobile phones, smart wear, and other devices?" determined the dependent variable. In this study, it was set as a binary variable, with the same control variables, and the same method was used to deal with variables. Finally, 12 other control variables were retained: gender, marital status, education level, nationality, religious belief, Hukou type, number of accompanying persons, working status, whether receiving pension insurance, social participation and willingness, and number of children.

As shown in **Table 8**, before sample matching, the average treatment effect was 0.414, which was significant at the 1% level. After sample matching, the average treatment effect was about −0.03 to −0.07. This shows that Internet use can increase depression or the frequency of depression in older adults and has a negative impact on their mental health, which is consistent with the results obtained above.

Heterogeneity Analysis

From the results presented above, we can draw the conclusion that Internet use reduces mental health and increases depression in older adults. However, the above results are only the average effect of the whole sample analysis, and the differences among different groups of older adults are not considered. To further study the impact of Internet use on mental health among different groups of older adults, this study also analyzed heterogeneity by gender, age, income level, Hukou type, education level, and number of accompanying persons. Similarly, to avoid endogeneity problems, the analysis results are based on PSM. Three methods such as k-nearest neighbor matching, radius matching, and kernel matching were used. The results are shown in **Table 9**.

In the heterogeneity analysis by gender, the average treatment effect for men was 0.054, significant at the 10% level, while the average treatment effect for women was 0.088, significant at the 1% level.

In terms of Hukou differences, we analyzed the overall older adult population as rural and non-rural samples for empirical purposes. Results show that the depressive tendencies of older adults with rural Hukou decreased by ∼6%, though it should be noted that the results are not significant. Contrastingly, the depressive tendencies of older adults in the non-rural group

TABLE 6 | Descriptive statistics of variables using the DID method.

Variables	Variable assignment	Mean (N = 3,840)	S.E.
Gender	Male = 1, female = 0	0.508	0.500
Nation	Han = 1, Minority = 0	0.936	0.244
Marriage	Married with spouse = 1, other = 0	0.659	0.474
Education	Primary = 0, Upper Secondary = 1	0.651	0.477
Religious	With religious beliefs = 1, no religious beliefs = 0	0.082	0.274
Com_num	Number of permanent residents with respondents	2.876	1.516
Hukou	Rural = 1, non-rural = 0	0.528	0.499
Work	Work status, work with income = 1, no job = 0	0.143	0.350
Pension	Getting basic endowment insurance = 1, not receiving basic endowment insurance = 0	0.580	0.494
Com_s	Level of community services; the lower the value, the higher the level of community service	17.83	0.956
Soc_s	Social support; the higher the value, the higher the degree of social support	13.59	5.979
Cld_num	Number of living children	2.746	1.483
Mental health	Depression tendency = 0, no depression tendency = 1	0.839	0.368
Soc_p	The higher the value, the stronger the willingness for social participation	19.58	10.68
Life satisfaction	Very satisfied = 1, relatively satisfied = 2, general = 3, less satisfied = 4, very dissatisfied = 5	2.131	0.902
Health	Very healthy = 1, relatively healthy = 2, general = 3, relatively unhealthy = 4, very unhealthy = 5	2.798	1.061
Net	Using Internet = 1, not using Internet = 0	0.095	0.293
Smartphone	Use smartphone = 1, not use smartphone = 0	0.157	0.364
Time	Year 2014 = 0, year 2016 = 1	0.500	0.500
Treated	Using Internet = 1, not using Internet = 0	0.095	0.293
gd	gd = time*treated	0.047	0.213

TABLE 7 | Difference-in-difference (DID) estimation for the effect of Internet use on mental health.

	Depression tendency	Standard error	$\|t\|$	$P > \|t\|$
Before using the internet				
Control group	1.026			
Treatment group	1.042			
Diff (T–C)	0.016	0.016	1.040	0.299
After using the internet				
Control group	0.807			
Treatment group	0.725			
Diff (T–C)	−0.082	0.038	2.170	0.030**
Diff-in-Diff	−0.099	0.040	2.450	0.014**

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

TABLE 8 | Results of the PSM and Chinese general social survey (CGSS) data.

Method	Sample	Using the internet	Not using the internet	ATT	S.E.
K-nearest	Before matching	4.057	3.643	0.414***	0.038
neighbor (n = 4)	After matching	4.057	4.131	−0.074	−1.03
Radius matching	Before matching	4.057	3.643	0.414***	0.038
	After matching	4.057	4.091	−0.034	0.069
Kernel	Before matching	4.057	3.643	0.414***	0.038
	After matching	4.057	4.093	−0.036	0.069

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

TABLE 9 | Results of heterogeneity analysis (PSM estimation).

Matching method	Gender		Age			Income levels	
	Male	Female	Low (60–69)	Middle (70–79)	High (80 and above)	Less than RMB 22,405	More than RMB 22,405
K-nearest neighbor ($n = 4$)	0.054*	0.088***	0.081***	0.081***	0.000	−0.010	0.127***
	(0.030)	(0.033)	(0.022)	(0.022)	(0.076)	(0.038)	(0.027)
Radius matching	0.054*	0.096***	0.075***	0.075***	0.009	−0.003	0.116***
	(0.027)	(0.030)	(0.020)	(0.020)	(0.070)	(0.034)	(0.025)
Kernel	0.054**	0.097***	0.075***	0.075***	0.014	−0.001	0.116***
	(0.027)	(0.030)	(0.020)	(0.020)	(0.070)	(0.034)	(0.025)

	Hukou		Education		Number of companions	
	Rural	Non-Rural	Primary	Upper secondary	Living alone	Not living alone
K-nearest neighbor (n=4)	−0.066	0.097***	0.087***	0.029	0.072	0.084***
	(0.049)	(0.024)	(0.029)	(0.033)	(0.076)	(0.023)
Radius matching	−0.060	0.092***	0.100***	0.030	0.077	0.084***
	(0.043)	(0.022)	(0.026)	(0.030)	(0.070)	(0.021)
Kernel	−0.060	0.093***	0.100***	0.029	0.074	0.085***
	(0.043)	(0.022)	(0.027)	(0.029)	(0.070)	(0.021)

*Standard errors are reported in the parentheses;*p < 0.1, **p < 0.05, ***p < 0.01.*

increased by about 9%, and the average processing effect was significant at the 1% level; therefore, it can be stated that the impact of Internet use on the mental state of older adults with non-rural Hukou is more pronounced.

In terms of differences in educational level, we divided the sample into two groups: primary and upper secondary education. The results showed that the average processing effect of the primary education sample was ∼10%, significant at the 1% level and that for the intermediate and higher education sample was 3%.

In terms of the number of companions, we divided them into older adults living alone and those not living alone. The results showed that the average processing effect of Internet use for the older adults living alone was 7%, while that for the non-older adult group was 8%, significant at the 1% level.

DISCUSSION

The Internet has a negative impact on the mental health of older adults, increasing their depressive tendencies. Nie and Erbring (10) argued that the Internet reduces opportunities for face-to-face communication with other members of society, leading to a sense of isolation, which is detrimental to the expression of emotions and the maintenance of social relationships. Using experimental data from 169 participants in 73 households, Kraut et al. (25) found that as Internet use increases, communication with family members decreases, while levels of loneliness and depression increase. This indicates that Internet use may replace some real-life social activities, which reduces social participation and produces negative psychosocial effects. Moreover, as the social circles of older adults continue to shrink due to factors like declining physical ability, Internet use can significantly increase their levels of loneliness.

Due to limited socialization after retirement in China, changes in the family structure with children leaving home for work, and fewer opportunities for social activities, face-to-face communication has been greatly reduced in the lives of older adults. Therefore, Internet use might further lessen their opportunities for emotional expression. The social support theory suggests that older adults receive material and emotional support by communicating and interacting with people or groups within their own social network, which enhances their sense of well-being. The mental health of older adults can be seriously affected when they lack emotional support from Internet use, resulting in negative emotions, such as depression. At the same time, when loneliness cannot be effectively alleviated in real life, older adults are likely to become overdependent on the Internet, resulting in addiction. The sense of emptiness and loss they feel when they return to reality after too much time on the Internet can further endanger their mental health.

Due to the late popularization of the Internet, the elderly in China often have poor computer literacy, which refers to the ability to use computers and software to complete practical tasks. Poor computer literacy can also affect their mental health in the process of use and difficulties in the process of operation can stimulate their anxiety. For example, while the elderly could get more information online to improve their mental health, negative content can mislead them, damaging their mental health. Yin and Neyens (34) found that about 62.3% of those with inflammatory bowel diseases reported they had looked up health information online, 16.3% reported they had scheduled an appointment with a health care provider online, and 21.6% reported having used a computer to communicate with a health provider by email.

Internet use is more likely to cause depression and has a stronger negative effect on the mental health of older women

than that of men. This is consistent with the findings of Yang and Lester (35), who reported that it was because older women were less skillful, and Schumacher and Morahan-Martin (36) found the older women had not received a good education and were different from men in terms of computer operation and its related aspects. In terms of age, this study was based on the treatment applied in the study by Peng et al. (37), which divided the population of older adults into three age groups: low (60–69 years old), middle (70–79 years old), and high (80 years old and above). The results are shown in **Table 9**, with the average treatment effect for "low" and middle-aged older adults being similar at around 0.08, both significant at the 1% level, while that for older adults was close to 0. Compared with older adults, the physical condition of middle-aged and young people is more ideal as they have more energy and find it easier to learn Internet skills; thus, the impact of Internet use is more evident. However, as older adults enter the advanced-age stage, their physical health worsens and they use the Internet less frequently. In the statistical samples, older adults only account for 0.3% of the sample data on Internet use, which is 2.6% of the total number of older adults who use the Internet. Therefore, the effect of Internet use was not evident.

This study used income level as a variable to investigate the impact of Internet use on the propensity score for depression in older age groups with different incomes because it is an important factor influencing the subjective well-being of an individual (38). The income groups were classified into two—below-average and above-average—based on the criterion that the average annual income is approximately RMB 21,792 (39). **Table 9** shows that the average treatment effect for the high-income group was about 0.1, higher than the low-income group, and is significant at the 1% level. This may be because financially stable older adults tend to use the Internet more (40) and thus suffer more pronounced shock effects. Moreover, people have the ability to adjust to changes in their environment. When their income increases, their expectations also rise and they quickly and automatically adapt to their increased income (41, 42). Therefore, as expectations rise and the desire for material well-being increases, Internet use allows people to more easily compare the lives of individuals with their own, creating a comparison effect and reducing their sense of well-being (28). Wu (43) argued that older adults have access to a more comprehensive range of information through the Internet. The influence of such information has led to more social comparisons among older adults, causing a decline in life satisfaction.

The difference between urban and rural may be due to the long-term influence of the urban–rural dualistic structure. In rural areas, Internet penetration is lower and the educational level of older adults is also relatively lower than their urban counterparts, which leads to a lower impact on their mental health. Ma and Le (44) indicated that these differences were caused by the late development of the Internet in rural areas, coupled with traditional concepts of production and life of premodern rural residents. Another reason is that urban older adults are more likely to be exposed to a more exciting world due to higher Internet usage. They are also more easily influenced by their new experiences, such as finding out about the lives of others through social networks and friend circles. However, discovering that others are better off than them can cause feelings of disappointment and loss. Due to the lack of a fixed retirement age among rural older adults, they still engage in agricultural labor after the age of 60, as opposed to those with non-rural Hukou. This enriches their activities in their later lives, leaving them with fewer inner desires. It also provides them with better mental health and life satisfaction.

Internet use has a greater impact on older adults with lower levels of education, increasing the likelihood of depression. This is in line with the findings of Peng et al. (37) who found that the effect of Internet use on subjective well-being is inhibited in older adults by primary school qualifications. It is possible that the effect is more pronounced because older adults with lower levels of education are less able and more reluctant to learn new technologies; they also find the learning process to be more complicated. In addition, anonymity on the Internet has become a "severe disaster area" of junk information such as violence, pornography, gambling, cults, and so on. Using the Internet to carry out illegal and criminal activities, like network fraud, has become increasingly rampant (45). Cao (46) found that the ability of individuals with higher education levels to identify and obtain information is greater than that of those who are less educated. The former has a knowledge advantage that enables them to search for useful information or distinguish between true and false information. Thus, older adults with lower education levels are more vulnerable to the negative effects of the Internet.

Internet use can disrupt the real-life relationships of older adults who do not live alone and spend more time with online interactions, than cultivating strong in-person ties (38). However, the negative impact of excessive Internet use on the mental health of older adults living alone was not evident due to their lack of companionship.

CONCLUSIONS

In light of the rapid spread of the Internet and mental health of older adults in China, we examined whether the use of the Internet can improve their mental health to help China achieve the goal of active aging and the Two Centenary Goals. We used the 2014 and 2016 CLASS data to scientifically answer this question. Our analysis yielded the following results. Overall, Internet use has a negative impact on the mental health of older adults, specifically an increased tendency to develop depression. To reduce the effect of endogenous problems, this conclusion still holds after a robustness analysis with the addition of a sample, a change of methodology, and a change in the sample. Considering the possible differences between different groups of older adults, we analyzed heterogeneity by age, gender, Hukou, income level, education level, and number of companions and found that Internet use has a stronger negative effect on mental health and is more likely to lead to depression in female older adults in the middle and lower age groups, high-income group, non-agricultural group, less educated group, and the group of older adults who do not live alone.

Based on these empirical results, we provide certain recommendations and insights in the following six areas to promote the rational use of the Internet by the older adult population of China in order to ensure a happy and active old age.

Improving attitudes toward Internet use among older adults and reducing their fear of the Internet. Raising awareness and improving attitudes toward Internet use can motivate older adults to use the Internet and reduce their fears. For example, Internet use can be integrated into community activities for older adults to increase their knowledge of the Internet and thus improve their attitudes toward its use. Older adults should adapt their mindset and take the initiative to learn the skills to use the Internet and related smart products to overcome their anxiety.

Developing the ability of older adults to use the Internet and reducing the sense of powerlessness in Internet use. In the age of the Internet, older adults are called digital refugees due to the limitations resulting from their educational background, behavioral habits, and age. They are generally less able to use the Internet and may even have a sense of technological panic, which seriously affects their physical and mental health. A targeted training service to building the capacity of older adults to use the Internet will help them bridge the digital divide and achieve active aging. Moreover, mobilizing the strength of society and family members through educational feedback and peer learning can effectively enhance the ability of older adults to use information tools.

Enhancing experience of older adults in using the Internet and, thus, their sense of well-being: Target audience of modern technology is mainly young people; however, there are significant differences between older adults and younger people in terms of physical function and psychological awareness, and their product designs are not suitable for older adults. For example, cluttered page layouts, small web fonts, and inappropriate content give older adults a poor user experience and damages their physical and mental health. Therefore, existing devices and applications need to gradually incorporate age-friendly design, especially considering the declining visual and auditory abilities of older adult users, and make age-appropriate changes in voice, text recognition, font size, etc., to enhance the experience of older adults.

Regulating the use of Internet content by older adults. Older adults, as a special group, are susceptible to the influence of inappropriate content on the Internet, which can be detrimental to their supervision of relevant content accessed by older adults when using the Internet and make use of big data to better tap the potential needs of older adults and provide them with targeted services and products that meet their actual needs.

Reasonable guidance for older adults using the Internet. Inappropriate use of the Internet refers to excessive use due to an inability to control the online behavior of an individual, which leads to significant psychological depression and waste of time, as well as failures in social interactions and family relationships. Internet addicts have less time for face-to-face interactions, which seriously affects their daily lives, interpersonal relationships, and sense of psychological well-being (47). Therefore, older adults, especially those with poor self-control, need to be reasonably guided in Internet use in order to develop good Internet habits, ensure a healthy lifestyle, take advantage of the positive effects of the Internet, and reduce its negative impact on their health.

Developing different support policies for different age groups. Through the heterogeneity analysis above, different groups of older adults should be provided with targeted services; for example, rural and less educated older adults, especially women, could be better trained to use the Internet and older adults living alone given priority to help develop relevant skills to meet their needs for social interaction, leisure, and entertainment.

The study has some limitations mainly related to the survey data. First, our analysis is limited to the sample, and caution is still needed when extrapolating our analysis to current situations. For that lifestyles of people, including their Internet use, have changed tremendously due to the pandemic contingency. Second, the measures used are relatively simple and do not allow for a more microscopic cognitive exploration of the psychological mechanisms at play between Internet use and mental health among older adults. In addition, the mechanisms and extent of the mental health effects are not yet clear. In spite of these, these limitations open up new research directions subsequent studies can consider and expand on. Further, this study provides a systematic analysis of the effect of Internet use on the mental status of older Chinese adults. It has important implications for Internet use promotion in China and other developing countries.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

LX and H-lY conceived this research. S-mT was responsible for the methodology. LX conducted software analyses. SZ and S-qZ conducted necessary validations. Y-yW conducted a formal analysis and managed the investigation. X-yL and S-mT gathered resources, curated all data, wrote/prepared the original draft, and were responsible for project administration. LX and W-lZ reviewed and edited the manuscript, were responsible for visualization, supervised the project, and acquired funding. All authors contributed to the article and approved the submitted version.

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Examining Rural and Racial Disparities in the Relationship Between Loneliness and Social Technology Use Among Older Adults

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Loneliness, the subjective negative experience derived from a lack of meaningful companionship, is associated with heightened vulnerability to adverse health outcomes among older adults. Social technology affords an opportunity to cultivate social connectedness and mitigate loneliness. However, research examining potential inequalities in loneliness is limited. This study investigates racial and rural-urban differences in the relationship between social technology use and loneliness in adults aged 50 and older using data from the 2016 wave of the Health and Retirement Study ($N = 4{,}315$). Social technology use was operationalized as the self-reported frequency of communication through Skype, Facebook, or other social media with family and friends. Loneliness was assessed using the UCLA Loneliness scale, and rural-urban differences were based on Beale rural-urban continuum codes. Examinations of race focused on differences between Black/African-American and White/Caucasian groups. A path model analysis was performed to assess whether race and rurality moderated the relationship between social technology use and loneliness, adjusting for living arrangements, age, general computer usage. Social engagement and frequency of social contact with family and friends were included as mediators. The primary study results demonstrated that the association between social technology use and loneliness differed by rurality, but not race. Rural older adults who use social technology less frequently experience greater loneliness than urban older adults. This relationship between social technology and loneliness was mediated by social engagement and frequency of social contact. Furthermore, racial and rural-urban differences in social technology use demonstrated that social technology use is less prevalent among rural older adults than urban and suburban-dwelling older adults; no such racial differences were observed. However, Black older adults report greater levels of perceived social negativity in their relationships compared to White older adults. Interventions seeking to address loneliness using social technology should consider rural and racial disparities.

Keywords: aging, loneliness, technology, rurality, disparities

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INTRODUCTION

Loneliness is a significant public health problem associated with poor physical and mental health outcomes (1). The prevalence of loneliness has more than doubled over the last 40 years. In the late 1970s, only 11–17% of middle-aged and older adults reported experiencing loneliness (2, 3), yet a recent report showed that over a third of Americans aged 45 and older report experiencing loneliness (4). With advancing age, the prevalence of loneliness also increases—43% of older adults aged 65 and older report feeling lonely (5). Given the prevalence and detrimental consequences of loneliness, it is crucial to examine interventions and tools that may mitigate loneliness, particularly among older adults. Recent findings suggest that low levels of loneliness are associated with high levels of internet-based social technology use among individuals aged 65 and older (6). Therefore, social technology may be a helpful tool that can be leveraged to address the pervasiveness of loneliness among older adults. However, there are numerous potential barriers to equitable access to technology, and disparities in the interaction between loneliness and technology remain unclear. Consequently, the purpose of this study is to bridge this gap by examining rural-urban differences and racial differences between Blacks/African-Americans and Whites/Caucasians in the relationship between social technology use and loneliness.

The construct of loneliness can be defined as the perceived lack of close and meaningful social relationships (7, 8). A related yet distinctive concept is social isolation, which refers to having few social contacts and social connections (7–9). Thus, social isolation is the objective absence of others in one's social milieu, and loneliness is the subjective negative feeling of being psychologically distant from others. While social isolation increases the likelihood that an individual will feel lonely, it is not necessarily a prerequisite for the experience of loneliness (2). For example, individuals with a large social network can still experience loneliness if they do not find sufficient close, meaningful connections in their network. On the other hand, socially isolated individuals who have a few meaningful, supportive relationships may find those connections sufficient to not feel lonely (2, 8, 10). Thus, the quality of one's relationships, rather than quantity, influences feelings of loneliness (11).

One of the key rationales for understanding loneliness and identifying ways to alleviate it is that loneliness is linked to a heightened risk of numerous health problems. Loneliness among middle-aged adults is associated with a 26% increased likelihood of mortality—a rate that is comparable to the individual mortality risks of cigarette smoking, obesity, and substance abuse (12). Loneliness can decrease one's quality of life. Longitudinal studies have demonstrated that lonely older adults are more likely to experience rapid declines in physical functioning, including activities of daily living and mobility (5, 13, 14). The detrimental health correlates of loneliness further extend to cognitive functioning and mental health. Loneliness has been linked with a heightened risk of cognitive decline and dementia (15–18). In terms of mental health, several studies have shown evidence that loneliness is associated with higher rates of depression and anxiety among middle-aged and older adults (10, 19–24). Collectively, numerous studies have provided unifying evidence that loneliness is predictive of serious negative physical, cognitive, and psychological consequences.

One possible way to mitigate the effects of loneliness could be through internet-based social technology, which refers to online technology platforms that allow for real-time video, voice, and instant messaging communication between people. Internet-based social technology includes such platforms as Zoom, Skype, WhatsApp, or Facebook (6, 25). If social technology effectively mitigates feelings of loneliness, it may lead to improved health among older adults. Interventions aimed at leveraging social technology must consider the challenges in digital access among older adults. Specific barriers to technology use among older adults include the physical limitations in vision and motor function, anxiety and lack of confidence with technology, perceived lack of usefulness and usability, and technological designs that are not suited for older adults (26–33). Despite these challenges, overall, older adults tend to have favorable views of technology (34, 35). Over 75% of older adults report that they believe the Internet has been a positive commodity for them personally (35). Similarly, other work has observed that older adults perceive technology as a means to acquire information, strengthen family ties, increase social connectedness, and increase the quality and quantity of social communication (27, 36). Once older adults have access to technology, it appears that the perceived benefits offset perceived challenges to technology use.

Several studies have demonstrated that technology use can have positive psychosocial impacts. Internet and technology use among older adults is associated with greater life satisfaction, and subjective well-being, decreased depressive symptoms, greater social engagement, and more social support (10, 34, 37–42). Numerous studies found that using the Internet for social communication purposes is associated with lower levels of loneliness (6, 27, 36, 42–44). One study demonstrated that the relationship between social technology use frequency and decreased loneliness was mediated by perceived social support (6). Social technology use can be an effective tool to foster social support, which subsequently can decrease feelings of loneliness. Other findings show that loneliness mediates the relationship between heightened social technology use and physical and mental health; loneliness may therefore represent a psychological mechanism that explains how social technologies can enhance older adults' health (34). This body of research establishes strong evidence that social technology use among older adults can be beneficial in developing and maintaining meaningful, supportive relationships.

However, there may be disparities in the relationship between loneliness and social technology use. Black/African-American and other racial and ethnic minority older adults tend to have less equitable access to health and social service resources compared to White/Caucasian older adults [e.g., (45–48)]. Prior research focused on Black/African American populations has demonstrated that support from social networks may mitigate these barriers (47, 49, 50). Given this past research showing that supportive social networks may be particularly

beneficial for Black/African-American racial minorities, the present study focuses specifically on racial differences in terms of Black/African-Americans and White/Caucasians. Research aimed at examining racial differences between Blacks/African Americans and Whites/Caucasians in loneliness and social isolation present mixed findings. Some work finds that Black older adults have smaller social networks, lower levels of social interaction, and greater levels of social isolation overall compared to White older adults (51, 52). An analysis using a demographic microsimulation model projected a doubling in the numbers of White kinless older adults by 2060, with a concomitant tripling among older Blacks over the same period (53). Socioeconomic disadvantage and health disparities among Black Americans contribute to an overall lifespan that is, on average, 3.5 years shorter than White Americans (54). Thus, loss of kin relationships into late adulthood is more likely to occur because family members, such as siblings, have higher rates of early mortality (53). Because kin are often a source of social support, racial inequalities in the burden of declining kin may disproportionately decrease social support and magnify the problem of loneliness among Black older adults in the future. However, other studies have not observed racial differences in loneliness (55) or social isolation (56–58). The majority of these studies have utilized large-scale, representative U.S. samples with similar outcome measures. Nevertheless, taken together, the inconclusiveness of this work underscores the need for further research to better understand racial differences in loneliness.

Similar to the relationship between race/ethnicity and loneliness findings, research that has sought to characterize rural-urban differences in loneliness also portrays complex, inconsistent results. On the one hand, several large-scale epidemiological studies in the United States (U.S.) and Canada have observed no association between rural-urban residence and loneliness (59–62). In contrast, other longitudinal research with U.S. populations shows that rural older adults report being able to rely on friends and family more than urban older adults (63). However, rural Black older adults report significantly higher levels of loneliness than other groups (63), suggesting that interactions between race and rurality may influence loneliness. Beyond this study, little research has examined how the interplay between race and rurality influences feelings of loneliness.

Although there is a strong link between social technology use and decreased loneliness in older adults, it is unclear whether there are racial or rural disparities in this relationship. Using data from the Health and Retirement Study, the present study examines whether the relationship between social technology use and loneliness differs by race and geographic region. Building on previous research, we propose the following hypotheses:

Hypothesis #1: Rural-dwelling older adults will report less social technology use compared to urban-dwelling older adults.
Hypothesis #2: Older Black adults will report less social technology use compared to older White adults.
Hypothesis #3: There will be a negative relationship between social technology use and loneliness such that lower social technology use will predict higher levels of loneliness.
Hypothesis 3a: This negative relationship is expected to be larger in magnitude among Black older adults compared to White older adults.
Hypothesis 3b: This negative relationship is expected to be larger in magnitude among rural-dwelling compared to urban-dwelling older adults.

METHOD

Data Source and Study Sample

The current study received ethics approval from Clemson University's Institutional Review Board before data acquisition. The data source for this research is the Health and Retirement Study (HRS), a nationally representative longitudinal study of Americans aged 50 and older that includes demographics, health, and cognitive measures. The HRS is an ongoing study conducted by the Institute for Social Research at the University of Michigan that was launched in 1992 (64, 65). Participants are surveyed in waves every 2 years. In 2006, the HRS introduced the Participant Psychosocial and Lifestyle Questionnaire (also called the "Leave-Behind" Questionnaire) that assesses numerous dimensions of psychosocial functioning (66). A subsample (50%) of respondents completes this survey during every biannual survey wave. The present study used data from the 2016 Core and Psychosocial and Lifestyle Questionnaire wave for all variables except the Beale-rural-urban continuum codes, which were not surveyed in 2016. Instead, Beale rural-urban continuum codes for the 2016 respondents were obtained by pooling data from the 2013 and 2003 HRS Cross-Wave Census Region/Division data waves (using the 2003 response if a 2013 response was missing).

Measures

Demographics

Demographic information (age, marital living arrangements, gender, and race) was retrieved from the 2016 Core and "Leave-Behind" Questionnaire datasets. Age was obtained from the participant's reported date of birth, which was then subtracted from the year they completed the survey (2016). Marital living arrangements indicate whether the participant had a spouse or partner with whom they live. Gender was dichotomized as male and female, and race was defined as non-Hispanic White/Caucasian, non-Hispanic Black/African American, American Indian/Alaskan Native, Asian, Hawaiian Native/Pacific Islander, and other.

Beale Rural-Urban Continuum Codes

The U.S. Department of Agriculture (USDA) developed this nine-category classification system to categorize counties based on their degree of metropolitan vs. non-metropolitan characteristics (67). In the HRS Dataset, these nine categories are grouped into three clusters: continuum code of 1 is categorized as urban (metropolitan areas with population $>$ 1,000,000), continuum code of 2 is categorized as suburban (metropolitan counties with a population of 250,000–1,000,000), and continuum code of 3–9 is categorized as rural (non-metropolitan counties with a population $<$ 250,000).

Social Technology Use

Following the approach from a recent study using the HRS dataset (6), social technology use was measured based on separate questions assessing self-reported frequency of social technology communication with children, other family members, and friends. Participants were asked "On average, how often do you communicate by Skype, Facebook, or other social media with any of your (children, other family members, friends) not counting any who live with you?" These three items were averaged such that higher scores reflect higher social technology use with family and friends. This measure was validated with older adults in previous research and showed high internal consistency [$\alpha = 0.87$; (6)].

Loneliness

The 11-item version of the Revised UCLA Loneliness Scale (68) was used to measure subjective feelings of loneliness and social isolation. Sample items include the frequency with which participants feel "part of a group of friends," "isolated (reverse-scored)," and "alone (reverse-coded)" using a 3-point Likert scale ($\alpha = 0.88$). This scale version has been validated in older adult populations and showed high internal consistency [$\alpha = 0.87$; (69)]. Sum scores were computed such that higher scores reflect higher levels of loneliness.

Perceived Social Support

The perceived social support items measure supportive relationships with family and friends (70, 71). Perceived social support was assessed through 12 separate questions regarding how well the participant feels their partner/spouse, children, other family members, and friends (a) understand the way they feel, (b) can be relied upon if they have a serious problem, and (c) they can open up to and talk about their worries based on a 4-point Likert scale ($\alpha = 0.81$). Higher scores indicate greater average levels of perceived social support.

Perceived Social Negativity

The perceived social negativity items measure strained relationship interactions with family and friends (70, 71). Participants responded to 16 separate questions about their perception of how their partner/spouse, children, other family members, and friends (a) make too many demands on the participant, (b) criticize the participant, (c) let the participant down when the participant is counting on them, and (d) get on the participant's nerves using a 4-point Likert scale ($\alpha = 0.86$). Higher scores reflect greater average levels of perceived social negativity.

Social Engagement

Social engagement, an index of social isolation, is defined as voluntarily participating in social activities. In line with previous research (72), social engagement was operationalized as the frequency of engagement in the following seven activities using a 7-point Likert scale ($\alpha = 0.66$): (1) work with children or young people, (2) do activities with grandchildren, nieces/nephews, or neighborhood children, (3) volunteer, (4) attend educational or training courses, (5) go to a sport, social, or other club, (6), participate in a local community arts group such as choir, dance, etc., and (7) attend meetings of non-religious organizations, such as political or community groups. Higher scores indicate more social engagement on average.

Social Contact

Social contact, a social isolation metric, was assessed through nine total items that asked about the frequency with which participants (a) meet up, (b) talk on the phone, or (c) write/email with their children, other family members, or friends using a 6-point Likert scale [$\alpha = 0.71$; (6)]. Higher values are indicative of greater social contact with family and friends.

General Computer Usage

A measure of participants' general computer usage was included as a covariate. Participants indicated the frequency in which they used a computer for email, Internet, or other tasks on a 7-point scale. Higher numbers indicate greater general computer usage.

Data Analysis

The categorical variable of race was categorized as non-Hispanic Black/African-American, other racial/ethnic group (including Asian, American Indian/Alaskan Native, and Native Hawaiian/Pacific Islander, and individuals who identified as "other"), or non-Hispanic White/Caucasian. The categorical variable rurality was operationalized as rural, suburban, or urban. Correlations were first performed to examine the bivariate relationships among continuous study variables: social technology use, loneliness, perceived social support, perceived social negativity, social contact, social engagement, and age. To test the hypothesis that rural-dwelling (Hypothesis 1) and Black (Hypothesis 2) older adults will report less social technology use, a two-way factorial ANOVA comparing differences in social technology use by race and rurality was performed.

To examine the effects of race, rurality, and social technology use on loneliness (Hypothesis 3), a path model was performed (**Figure 1**). The social isolation metrics of social engagement and social contacts were included as mediators as these constructs related to social isolation. Sum scores of the constructs were used in the path model. To illustrate potential broader, downstream consequences of social technology use, perceived social negativity and perceived social support were also included in the model. The covariates marital living arrangements, age, and general computer usage were also included in the model. In order to enhance the robustness of the model, we used a maximum likelihood estimation with robust standard errors ("mlr") and used the "lavaan" package in R to conduct the analyses.

RESULTS

Sample Demographics

After pooling data across waves and excluding participants who reported being younger than age 50 at the time of responding ($n = 68$), the dataset used for the path model analysis contained 4,315 observations without missing data ($M_{age} = 69.79$, $SD_{age} = 9.86$, 60.6% female). For analytic purposes, we stratified race as non-Hispanic White/Caucasian (76.64% of the sample),

TABLE 1 | Demographic variables ($N = 4{,}315$).

Variable	Mean	Standard deviation
Age	69.79	9.86
Variable	***n***	**%**
Gender		
Female	2,616	60.6%
Male	1,699	39.4%
Race		
Non-Hispanic White/Caucasian	3,306	76.64%
Non-Hispanic Black/African-American	692	16.01%
Other racial/ethnic backgrounds	317	7.26%
Marital living arrangement		
Lives with spouse	2,674	62.0%
Does not live with spouse	1,641	38.0%
Beale codes		
Urban	2,241	51.9%
Suburban	958	22.2%
Ex-urban/rural	1,116	25.9%

non-Hispanic Black/African-American (16.01% of the sample), and members of other racial/ethnic backgrounds (7.26% of the sample). The other racial/ethnicity group was aggregated into a single category due to small sample sizes for each of these individual racial/ethnic groups [American Indian/Alaskan Native ($n = 43$), Asian ($n = 57$), Native Hawaiian/Pacific Islander ($n = 7$), and Other ($n = 210$)]. Within the other racial/ethnic group category, 210 participants identified as "other" which may include some individuals who self-identify as Hispanic/Latino as well as multiracial individuals. We note that for the ANOVA ($N = 5{,}241$) and ancillary correlations ($N = 5{,}178$), the sample contained more than the number of observations for the path model analysis. Demographic information for the path model analysis is shown in **Table 1**.

Measures of Social Technology Use, Loneliness, and Social Isolation

The average social technology use across all participants was 2.46 ($SD = 1.70$, range = 1–6) on the 6-point scale. Using the response scale, this mean value reflects an average social technology use between "once or twice a year" and "every few months." A Kruskal-Wallis one-way ANOVA demonstrated social technology use differences by rurality ($p < 0.001$) but not by race ($p = 0.47$) such that rural-dwelling older adults reported less social technology use than suburban or urban-dwelling older adults. **Table 2** shows additional descriptive information for the continuous variables stratified by race and rurality.

Relationships Between Social Technology Use, Loneliness, and Social Isolation Measures

Results revealed significant correlations among almost all continuous variables. Social technology use showed a significant moderate positive association with frequency of social contact ($r = 0.47$, $p < 0.01$), and significant but weak positive association with perceived social support ($r = 0.16$, $p < 0.01$) and frequency of social engagement ($r = 0.22$, $p < 0.01$). Furthermore, there was a significant moderate negative relationship between social technology use and age ($r = -0.33$, $p < 0.01$), and significant negative, albeit weak, association between social technology use and loneliness ($r = -0.12$, $p < 0.01$). **Table 3** shows the correlations among the other continuous study variables.

Two-Way Factorial ANOVA Comparing Differences in Social Technology Use

The ANOVA examining differences in social technology use by race and rurality showed a significant main effect of rurality ($p = 0.014$) such that rural older adults ($M = 2.32$, $SD = 1.66$) reported significantly lower social technology use than older adults living in urban ($M = 2.53$, $SD = 1.71$) and suburban ($M = 2.54$, $SD = 1.72$) regions. There was no main effect of race ($p = 0.55$) or interaction ($p = 0.40$). **Table 4** shows the ANOVA results.

Path Model Analysis

Mediation Effects

The results of the path model showed that the effect of social technology use on loneliness was partially mediated by social contact and social engagement. **Table 5** shows the direct and indirect effects of the mediation analyses. Despite the direct positive main effect of social technology use on loneliness, using social technology increases social contact and social engagement and overall mitigates loneliness. Results of the full model are shown in **Figure 2**.

Loneliness

Both social technology use * race and social technology use * rurality two-way interactions and three-way interaction effects between race, rurality, and social technology use were tested. The three-way interaction effects were not significant. The primary study result is reflected by a significant two-way interaction between rurality and social technology use (p omnibus = 0.034). This effect was localized to rural older adults (rural: $\beta = -0.106$, $p = 0.011$; suburb: $\beta = -0.059$, $p = 0.187$) such that rural older adults who use social technology more often reported higher levels of loneliness compared to urban-dwelling older adults (**Figure 3**). Results also revealed a main effect of rurality on loneliness (p omnibus = 0.041). Specifically, rural residents reported significantly higher levels of loneliness compared to urban residents (rural: $\beta = 0.091$, $p = 0.018$; suburb: $\beta = 0.070$, $p = 0.093$). The main effect of race on social technology use was not significant (p omnibus = 0.093). Furthermore, individuals with greater social engagement reported lower levels of loneliness ($\beta = -0.111$, $p < 0.001$). The direct effect of social technology use also significantly predicted loneliness ($\beta = 0.057$, $p = 0.034$). No other effects were significant. The model accounts for 12.6% of the variance in loneliness.

Social Engagement

Path models results with social technology use, race, rurality, and the covariates predicting social engagement revealed a significant

TABLE 2 | Descriptive information for primary study variables stratified by race and rurality ($N = 4,315$).

Stratification by race

Variable	Score range	Black/African American ($N = 692$)	Other racial group ($N = 317$)	White/Caucasian ($N = 3,306$)	Total	*P*-value[a]
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Social technology use	1–6	2.47 (1.73)	2.58 (1.74)	2.47 (1.69)	2.48 (1.70)	0.47
Loneliness	11–33	17.11 (4.80)	17.65 (4.81)	16.59 (4.79)	16.75 (4.80)	<0.001*
Social contact	1–6	3.61 (0.89)	3.62 (0.93)	3.72 (0.85)	3.69 (0.86)	0.002*
Social engagement	1–7	2.07 (0.86)	1.94 (0.84)	1.99 (0.77)	2.00 (0.79)	0.08
Social support	1–4	3.15 (0.56)	3.12 (0.56)	3.14 (0.54)	3.14 (0.54)	0.55
Social negativity	1–4	1.72 (0.54)	1.76 (0.56)	1.60 (0.44)	1.63 (0.47)	<0.001*
General computer use	1–7	4.43 (2.66)	4.52 (2.64)	5.10 (2.57)	4.95 (2.61)	<0.001*

Stratification by rurality

Variable	Score range	Rural ($N = 1,116$)	Suburban ($N = 958$)	Urban ($N = 2,241$)	Total	*P*-value[a]
	Range	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Social technology use	1–6	2.32 (1.66)	2.54 (1.72)	2.53 (1.71)	2.48 (1.70)	0.001*
Loneliness	11–33	17.06 (4.76)	16.87 (4.89)	16.55 (4.78)	16.75 (4.80)	0.003*
Social contact	1–6	3.58 (0.82)	3.72 (0.86)	3.74 (0.88)	3.69 (0.86)	<0.001*
Social engagement	1–7	1.97 (0.76)	2.00 (0.82)	2.02 (0.79)	2.00 (0.79)	0.23
Social support	1–4	3.12 (0.55)	3.15 (0.54)	3.15 (0.54)	3.14 (0.54)	0.20
Social negativity	1–4	1.61 (0.45)	1.63 (0.49)	1.64 (0.48)	1.63 (0.47)	0.40
General computer usage	1–7	4.43 (2.77)	4.86 (2.62)	5.24 (2.47)	4.95 (2.61)	<0.001*

[a]*Indicates the results of a Kruskal-Wallis test. * indicates significance at the $p < 0.05$ level.*

TABLE 3 | Correlational analyses ($N = 5,178$).

Variable	Social tech. use	Loneliness	Social support	Social negativity	Social engagement	Social contact
1. Social technology use						
2. Loneliness	−0.12**					
3. Social support	0.16**	−0.51**				
4. Social negativity	0.07	0.36**	−0.34**			
5. Social engagement	0.22**	−0.19**	0.10**	0.08**		
6. Social contact	0.47**	−0.30**	0.41**	−0.07**	0.33**	
7. Age	−0.33**	−0.02	0.05**	−0.22**	−0.14**	−0.08**

** *indicates significance at the $p < 0.01$ level.*

main effect of race on social engagement (p omnibus = 0.003). Black older adults reported higher levels of social engagement than White older adults ($\beta = 0.177$, $p = 0.001$). Greater social technology use ($\beta = 0.093$, $p < 0.001$), lower levels of general computer usage ($\beta = -0.073$, $p < 0.001$), and living with a partner predicted higher social engagement. No other significant effects were observed.

Social Contact

Omnibus test results for frequency of social contact with family and friends suggested a significant interaction between social technology use and race (p omnibus = 0.048); members of other racial/ethnic backgrounds, including Asian, American Indian/Alaskan Native, Native Hawaiian/Pacific Islander, and those self-identifying as "other," who use social technology more have greater social contact ($\beta = 0.119$, $p = 0.021$). A significant main effect of race on social contact (p omnibus = 0.011) showed that Black older adults reported significantly less contact with family and friends than White older adults ($\beta = -0.138$, $p = 0.005$). Rurality was also a significant predictor of social contact (p omnibus < 0.001) such that those living in rural regions reported significantly less social contact compared to those living in urban areas ($\beta = -0.127$, $p < 0.001$). Greater social technology use is also associated with greater social contact ($\beta = 0.338$, $p < 0.001$). Less frequent general computer use ($\beta = -0.077$, $p < 0.001$), older age ($\beta = 0.010$, $p < 0.001$) and living without a partner ($\beta = -0.131$, $p < 0.001$) predicted greater social contact frequency.

TABLE 4 | Two-way factorial analysis of variance results on the effect of race and rurality on differences in social technology use ($N = 4{,}315$).

Source of variance	Degrees of freedom	*F*	*p*
Race	2	0.60	0.55
Rurality	2	4.28	0.01*
Race*rurality interaction	4	1.01	0.40
Error	4,306	2.89	

*Levels of race include Black/African-American, members of other racial/ethnic backgrounds, and White/Caucasian. Levels of Rurality include urban, suburban, and rural. * indicates significance at the $p < 0.05$ level.*

TABLE 5 | Effect of social technology on loneliness as mediated by social contact and social engagement.

Paths	Estimate	S.E.	*p*-value
Direct path			
Social technology use → loneliness	0.057	0.027	0.034
Indirect paths			
Social technology use → social contact → loneliness	−0.114	0.013	<0.001
Social technology use → social engagement → loneliness	−0.010	0.004	0.005
Total effect	−0.067	0.026	0.010

S.E. refers to standard error.

Perceived Social Support

Model results showed that loneliness was predictive of diminished perceived social support ($\beta = -0.484$, $p < 0.001$). Living with a partner was also associated with lower social support ($\beta = -0.085$, $p < 0.01$). No other significant effects were observed.

Perceived Social Negativity

A significant main effect of race on perceived social negativity (p omnibus $= 0.001$) revealed that both Black older adults and members of other minority races reported experiencing greater perceived social negativity (βs $= 0.147, 0.142$, ps < 0.01). There was also a significant main effect of loneliness in which lonelier older adults perceived greater social negativity ($\beta = 0.304$, $p < 0.001$). Greater general computer usage ($\beta = 0.021$, $p < 0.001$), younger age ($\beta = -0.020$, $p < 0.001$), and living with a partner ($\beta = 0.157$, $p < 0.001$) was associated with greater perceived social negativity.

DISCUSSION

Previous research has shown that older adults who engage in more frequent online social communication tend to be less lonely (6, 27, 36, 42–44). Correlational results from the present study are largely consistent with this work; greater frequency of internet-based social technology use was associated with lower levels of loneliness among older adults. While this result supports our hypothesis, we note that the observed strength of this relationship was relatively weak. Furthermore, internet-based social technology use and was associated with greater perceived social support and lower levels of social isolation, as measured by frequency of social contact and social engagement. These findings suggest that internet-based social technology use may present a tool to foster social support and connectedness among older adults.

The results of this study extends previous research on loneliness and social technology use by showing that the association between social technology use and loneliness is mediated by frequency of social engagement and social contact with friends and family; these mediators align with social isolation constructs. Although the direct effect of social technology on loneliness was positive, in the context of these mediators, the total effect of social technology use, mediated by social engagement and social contact, predicted lower levels of loneliness. Therefore, in addition to the observed rural disparity finding, this study provides a putative mechanism for the relationship between social technology use and loneliness: social technology use predicts increased frequency of social engagement and contact with family and friends, which in turn is predictive of reduced feelings of loneliness.

The present study also investigated racial and rural differences in the relationship between social technology use and loneliness. We predicted that there would be a negative relationship between loneliness and social technology use that would be exacerbated among Black and rural-dwelling older adults. The primary findings demonstrate that the association between loneliness and social technology use differed by rurality but *not* by race. Rural older adults who use social technology less frequently experienced higher levels of loneliness than urban older adults.

In addition to these findings, we further hypothesized that social technology use would be less prevalent among Black and rural older adults. The data supported the hypothesis for rurality but not the hypothesis for racial differences in social technology use. This finding is consistent with studies showing that individuals living in rural areas are less likely to use online technology than those in urban regions (73). Although rural older adults use social technology less than urban older adults, the benefits of technology in fostering social connectedness have previously been observed in rural communities (74). Moreover, the mediation results of the present study bolster these findings by showing that social technology use is associated with increased social engagement and contact with family and friends. Rural regions often have fewer central gathering places and opportunities to interact with neighbors, which can increase social isolation (10, 75). Social technology offers an alternative means for communication and socialization that can be capitalized on to reduce feelings of loneliness among older adults aged 50 and older. Given the rural disparities in technology use and the corresponding increase in loneliness, further research is needed to better understand the unique challenges rural older adults face in social technology utilization. Elucidating the major barriers to social technology use and implementing interventions to overcome these barriers among the at-risk rural

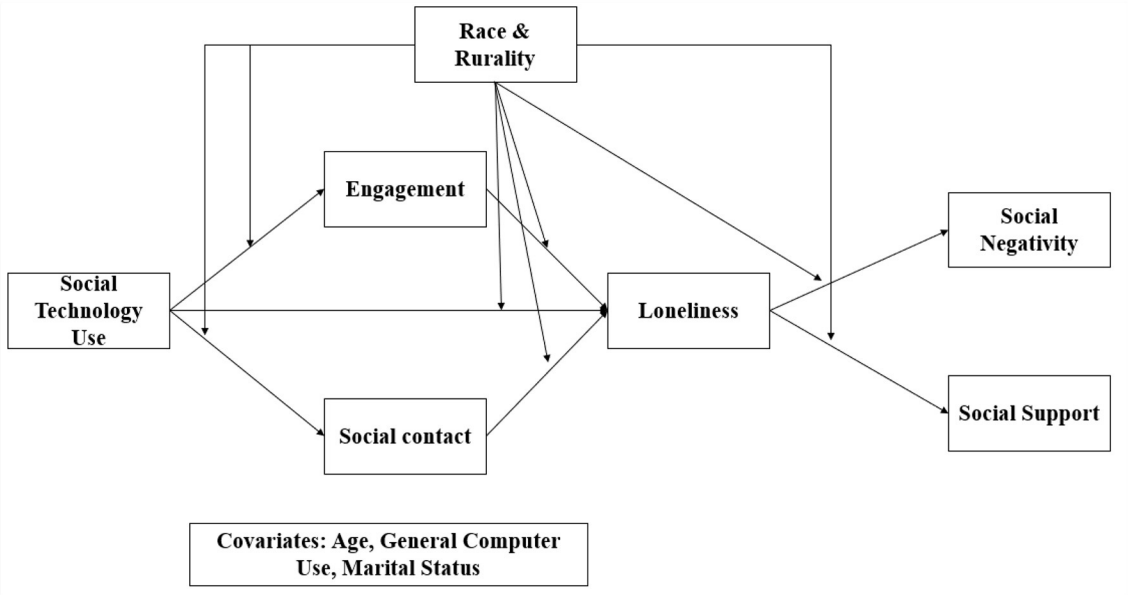

FIGURE 1 | Conceptual model of the relationship between social technology use and loneliness. Race (White/Caucasian, Black/African American, and members of other racial/ethnic backgrounds) and rurality (rural suburban, and urban) were examined as moderators. Social engagement and social contacts were included as mediators of this putative relationship. Age, marital living arrangements (live with spouse/partner vs. not), and frequency of general computer usage were included as covariates in the model.

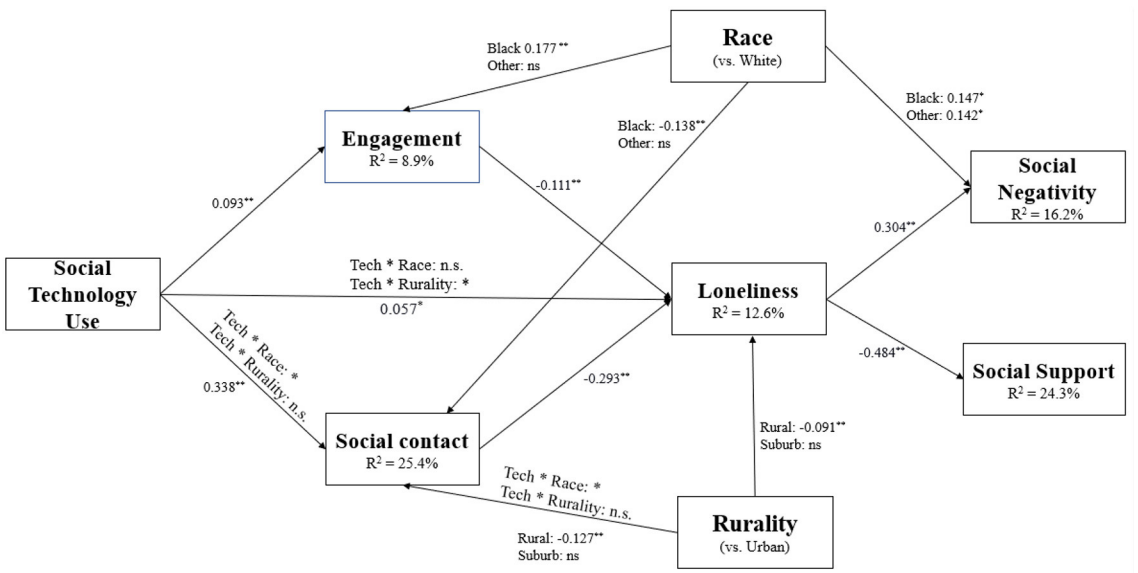

FIGURE 2 | Path model results ($N = 4,315$) of the path model with social technology use predicting loneliness as moderated by race and rurality and mediated by social engagement and social contacts. The figure shows direct paths between variables. Path parameters represent standardized coefficients. *indicates $p < 0.01$. **indicates $p < 0.001$.

older adults, such as technology training, adaptive interface designs for age-related decline, or hands-on services to deliver technology resources to rural regions, may be key to reducing loneliness and the associated health consequences of loneliness in this population.

Further analyses examining potential racial and rural differences in loneliness, social contact, social negativity, and social support were also performed. Rural individuals had fewer social contacts than urban individuals and experienced greater loneliness, which varies from prior studies that did not observe

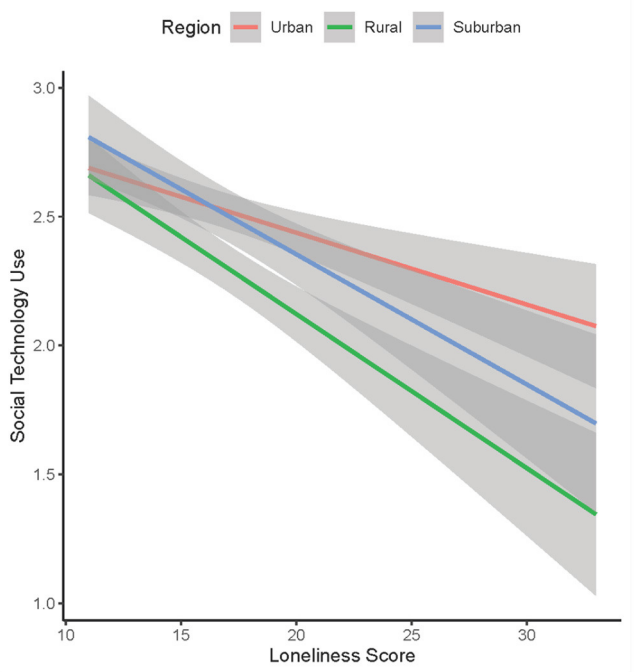

FIGURE 3 | Relationship between loneliness and social technology use by rurality. The magnitude of the negative relationship between loneliness and social technology use was stronger among rural older adults than urban older adults.

differences in rurality on loneliness (59–62). Differences in design methodology and sample demographics, including age and country of residence, may potentially contribute to these differences. Given the important consequences associated with loneliness, these findings underscore the need for further large-scale, longitudinal research that directly evaluates the impact and potential mechanisms of rural-urban differences in loneliness.

Results for racial differences showed that Black older adults had fewer social contacts and encountered more social negativity in their relationships than White older adults, although they had greater social engagement. These results are in line with prior research showing that Black older adults have smaller social networks compared to White older adults (51, 52). Study results did not show significant racial differences in loneliness, which supports prior research (55). The heightened social negativity among Black older adults is particularly concerning. The widespread discrimination that afflicts Black Americans is associated with increased risk of mortality and poor physical and psychological outcomes [e.g., (76–80)]. Merging the discrimination literature and the present study's findings, it appears that there may be compounding threats of social discrimination and social negativity from family and friends that disproportionately impact Black older adults. These threats pose serious health risks, and future research is needed to address the social inequalities that Black older adults encounter.

Moreover, study findings indicated that greater levels of loneliness were associated with significantly greater perceived social negativity and less perceived social support. This result echoes the conceptualization of loneliness as the subjective experience resulting from a dearth of supportive, meaningful relationships (7, 8). Loneliness among older adults appears to encompass the psychological experience of being burdened by draining social relationships that do not provide reliable support. Lack of social support can dampen psychological resources needed to adapt to age-related life changes and challenges, which can potentially compound health problems (24).

Limitations and Future Directions

In considering the limitations of this study, it should be noted that the study utilized a cross-sectional correlational design, and causal relationships between social technology use and loneliness cannot be established. As previous research has noted, a self-selection bias could influence this relationship such that individuals who are more open to using social technology experience lower levels of loneliness (6). Future work utilizing randomized controlled trials with social technology interventions or longitudinal designs are needed to establish a causal relationship between social technology use and loneliness and the corresponding rural disparities in this relationship.

Moreover, in this study, social technology use was defined as the frequency of communication using Skype, Facebook, or other social media with friends and family. It is unclear which social technology platforms are particularly beneficial, and a fine-grain examination of the platforms and platform features that foster social benefits among older adults may be useful in identifying ways to increase social technology use in this population. Similarly, the reasons that rural older adults who use social technology less often tend to be more lonely than urban older adults were not explored as part of this investigation. Future research identifying the mechanisms of rural disparities in the relationship between loneliness and social technology use needs to be established.

We also note that the present investigation merged non-White/Caucasian and non-Black/African-American participants from other racial and ethnic groups into a single category due to sample size constraints. The results of this study cannot be generalized beyond White/Caucasian and Black/African-American groups, and it is unclear how the relationship between loneliness and social technology use may differ among Hispanic/Latino ethnic groups or Asian, Native American, or Pacific Islander racial groups. Additional research is needed to better characterize ways to reduce loneliness is these ethnic and racial groups.

Conclusions

This work sought to characterize rural and racial disparities in the association between loneliness and online social communication frequency. This study provides evidence of rural, but not racial, disparities in the link between social technology and loneliness. Low social technology use is associated with greater loneliness among rural older adults compared to urban older adults. One potential implication from this work is that the benefits of social technology may be particularly impactful for rural older adults in combatting loneliness. Methods

to increase social technology use among rural older adults may be beneficial in reducing loneliness and could, in turn, help alleviate the detrimental health consequences associated with loneliness.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://hrs.isr.umich.edu/.

ETHICS STATEMENT

This study involving secondary data analysis of research with human participants was reviewed and approved by Clemson University Institutional Review Board. Participants were part of the Health and Retirement Study (HRS) and provided their written informed consent to participate in the HRS study.

AUTHOR CONTRIBUTIONS

KB and SL contributed to the conceptualization of the study. RA performed data extraction, organization, and statistical analyses. BK provided guidance on the statistics. KB wrote the first draft of the manuscript. KC, CD, LR, BK, and SL reviewed the manuscript and provide critical feedback. All authors contributed to the manuscript revision, read, and approved the submitted version.

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Social Support, Isolation, Loneliness, and Health Among Older Adults in the PRISM Randomized Controlled Trial

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Objectives: Social isolation and loneliness are serious public health issues given the association with negative physical, mental; and cognitive health outcomes and increased risk for mortality. Due to changes in life circumstances many aging adults are socially isolated and experience loneliness. We examined the relationships among four correlated but distinct constructs: social network size, social support, social isolation, and loneliness as they relate to indices of health and wellbeing among diverse subpopulations of older adults. Guided by WHO's International Classification of Functioning, Disability and Health (ICF) we also examined factors that predict loneliness and social isolation.

Methods: Analyses of baseline data from sample of older adults who participated in an intervention trial that examined the beneficial effects of a software system designed to support access to resources and information, and social connectivity. Participants included 300 individuals aged 65–98, who lived alone, were primarily of lower socio-economic status and ethnically diverse. Participants completed a demographics questionnaire, self-report measures of health, depression, social network size, social support, and loneliness.

Results: Loneliness was strongly associated with depression and self-ratings of health. In turn, greater social isolation and less social support were associated with greater loneliness. Social isolation was associated with depression and lower self-ratings of health. The association between social isolation and health was mediated by loneliness. Individuals in the older cohorts (80+) reported less social support. With respect to loneliness, having a smaller social network, more functional limitations, and limitations in engaging meaningful activities was associated with higher levels of loneliness and greater social isolation.

Conclusion: The findings underscore the importance of social connectively to wellbeing for older adults and suggest that those in the older cohorts, who have a small social network, and with greater physical and functional impairments may be particularly vulnerable to being socially isolated and lonely. The findings provide guidance for

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future interventions. In this regard, we discuss how Information and Communication Technologies (ICTs) may be used to promote social connectivity and engagement. Strategies to make the usability and availability of these applications for aging adults are highlighted.

Keywords: social Isolation, loneliness, older adults, technology, health

INTRODUCTION

The number of people in the United States aged 65+ will increase to about 98 million by 2060, with the fast-growing cohort of the "oldest old" (85+) projected to number 14.6 million by 2040 (Administration for Community Living, 2020). The burgeoning population of older adults especially those in the "oldest old" cohort (85+) has given rise to concern about the need for strategies to maintain the health and independence of this population.

Recently, increased attention has been directed toward social isolation and loneliness as significant health risks for aging adults. Changes in life circumstances, such as retirement, loss of partners or friends, financial circumstances, health declines, and mobility challenges make older people vulnerable to becoming isolated and lonely. Current estimates suggest that approximately, one-quarter of community dwelling adults aged 65 and older are socially isolated (Anderson and Thayer, 2018) and that almost half (43 percent) of those 60 and older reported feeling lonely (Cudjoe et al., 2020). The growing concerns about social isolation and loneliness among aging adults is underscored by the recent consensus study by National Academies of Science Engineering and Medicine (2020) that focused on social isolation and loneliness in older adults. One conclusion was that social isolation and loneliness play as large a role as other well-established risk factors for negative health consequences such as obesity and smoking (Donovan and Blazer, 2020).

Substantive results in the literature link social isolation and loneliness to heightened risk for physical difficulties, mental health problems, cognitive deficits, functional declines, and mortality (e.g., Cacioppo et al., 2010; Holt-Lunstad et al., 2010; Aylaz et al., 2012; Perissinotto et al., 2012; Valtorta et al., 2016; Hakulinen et al., 2018; Jeuring et al., 2018; Domenech-Abella et al., 2019; Read et al., 2020). Data from the English Longitudinal Study of Aging indicated that loneliness is a significant, independent predictor of dementia (Rafnsson et al., 2017).

Current models of "successful aging" (e.g., Rowe and Kahn, 1988; Kahana and Kahana, 1996, 2001) posit that engagement in productive and social activities is key to successful aging. Social engagement is multifaceted and includes personal relationships, connections with the community (e.g., neighborhood), and engagement with society. Personal relationships provide social support and opportunities for reciprocal communication and feeling valued or mattering. Connection with the community fosters a sense of belonging; participation in society provides opportunities to contribute and engage with ideas. Recently, the term social capital has been used in discussions of social engagement and generally refers to resources available to individuals and groups through social connections and their community (Cannuscio et al., 2003).

With the increasing number of adults in the older cohorts and other demographic trends, such as geographical dispersion of families and changes in family structures, social isolation will continue to be an issue in the foreseeable future. This is especially true in light of the COVID-19 pandemic where stay-at-home requirements curtailed opportunities for face-to-face interactions, participation in social activities, and access to social networks and support. Much is being written about the potential implications of the enforced social restrictions on mental health and well-being (e.g., Armitage and Nellums, 2020; Wu, 2020). As noted by the NASEM report (2020) social isolation and loneliness are modifiable risk factors for health and although much has been written about the link between social isolation and loneliness and health consequences, the literature on effective interventions to remediate existing problems with social isolation and loneliness and prevent further incidence for vulnerable individuals is limited. Development of efficacious intervention strategies requires understanding how to best assess social isolation and loneliness; the prevalence and predictors of isolation and loneliness; and variations within subpopulations.

Social isolation and loneliness are distinct constructs, which are related but only moderately correlated. Social isolation can be measured objectively and refers to social network size and the existence and interconnections among different social ties. Loneliness is subjective and refers to a person's self-perceived lack of social support and companionship. Social support refers to the provision of emotional, instrumental, or informational resources to help an individual cope with stress and life events (Cohen, 2004) and is related to social connectivity. However, the provision of support does not necessarily imply that an individual is satisfied with the support received. There are various measures of these constructs available, which contributes to the inconsistencies among findings regarding the prevalence of social isolation, loneliness, and social support among older people and association of these variables with health and well-being outcomes. Additionally, few studies have examined these factors conjointly. Coyle and Dugan (2012) stressed that it is important to distinguish between social isolation and loneliness when examining health outcomes in older adults as they are different constructs and may have differential impacts on indices of health.

In this study, we had the unique opportunity to examine the relationships among aspects of social engagement and the relationships of these factors to health outcomes among a large and diverse sample of older adults who live alone in the community. Although living alone has been associated with higher rates of isolation and loneliness, the relationship

between living alone and these factors is complex. As noted by Perissinotto and Covinsky (2014), we cannot assume that people who are living alone are lonely or lacking in social connectivity and support. We examined how these relationships vary among cohorts of older adults (younger-old and older-old) as there is heterogeneity across older age cohorts on numerous variables. For example, those in older cohorts are more likely to have fewer social connections and greater role limitations due to changes in life circumstances, health, and mobility issues. In addition, we examined how social isolation and loneliness influence physical and emotional health outcomes and cognition. We examined these outcomes separately as the literature suggests that the predictors of these outcomes may vary. Understanding the unique factors associated with distinct outcomes is important to the design of intervention strategies. Finally, guided by the WHO Model of Functioning, Disability, and Health (World Health Organization, 2002), we examined personal (e.g., income, age), community (e.g., social network), and health factors (e.g., health conditions) that are associated with social isolation and loneliness. The WHO model provides a framework for understanding health outcomes and determinants. Based on the substantive literature, examining the impacts of social isolation and loneliness, we hypothesized that loneliness and social isolation would be independent predictors of depressive symptoms, health, and cognition. We also wished to examine if social support and loneliness impacted our outcomes through different mechanisms. In addition, we hypothesized, given that an important aspect of loneliness is a sense of not being integrated into a social environment (Tiikkainen and Heikkinen, 2005), that social support would be related to loneliness such that those with lower perceived social support would report higher levels of loneliness. Further, as we had measures of both the structural and functional aspects of social connectivity, we hypothesized that social network size and social isolation would be related to perceived social support.

MATERIALS AND METHODS

The sample for the analyses was comprised of participants in the Personal Reminder, Information, and Social Management (PRISM) randomized field trial (Czaja et al., 2015, 2018), which examined the benefits of a computer system designed to support access to social connectivity and support access to information, and engagement among older people. We present a summary of the PRISM trial as the methods and the main outcomes of the trial have been previously reported (Czaja et al., 2015, 2018).

Protocol

Potential participants contacted the site study coordinator and completed a telephone screening that assessed eligibility. For those eligible, a home baseline assessment was scheduled. During this assessment participants provided informed consent. An assessor trained and certified in the study protocol administered the assessment. Participants were compensated $25 for the assessment. Participants were then randomly assigned to the PRISM condition or a Binder Control condition. Those in the PRISM condition received hardware and software training and had the PRISM system installed their home for 12 months. Those in the Binder Control condition received a binder containing content that paralleled the PRISM system in a non-electronic form (e.g., paper resource guides, paper calendar). PRISM included Internet access (with vetted links to sites such as NIH SeniorHealth.Gov); an annotated resource guide; a dynamic classroom feature; a calendar; a photo feature; email; games; and online help. Participants also completed 6- and 12-month follow-up assessments administered by assessors blinded to treatment condition. The Institutional Review Boards at the sites approved the study and all participants provided informed written consent. Here we report on data from the baseline assessment from all study participants.

Sample

We recruited 300 older adults at risk for social isolation, operationalized as: lived alone, did not spend more than 10 h each week at a Senior Center, did not work or volunteer for more than 5 h per week, and had minimal computer and Internet experience in the past 3 months. Eligible participants were 65 years of age or older, spoke English, and could read at the 6th grade level. Participants were recruited through advertisement and various outreach methods [e.g., churches, community organizations from the Atlanta (GA), Miami (FL), and Tallahassee (FL) regions of the United States]. The sample was primarily female (78%) and ranged in age from 65 to 98 years (M = 76.15, SD = 7.4); 33% of the sample was ≥80 years and 15% were 85+ years. Participants were ethnically diverse (46% non-White), 89% had annual household incomes <$30,000, and 39% had high school or less education (Czaja et al., 2015).

Measures

The full list of measures collected in the trial is available in Czaja et al. (2015). The present study focused on the indices of: social isolation (Friendship Scale – Hawthorne, 2006; $\alpha = 0.75$); loneliness (The UCLA Loneliness Scale – Russell, 1996; $\alpha = 0.91$); social support (Interpersonal Support Evaluation List, ISEL; Cohen et al., 1985); Social Network Size (Lubben Social Network Index; Lubben, 1988; $\alpha = 0.85$); depressive symptoms (20 item Center for Epidemiological Depression Scale, CESD; Radloff, 1977; Irwin et al., 1999; $\alpha = 0.87$); and a self-rating of overall health. We used the common single item self-rating of health ("In general, would you say your health is" with the response items "excellent, very good, good, fair, or poor"), which has predictive validity with respect to objective measures of health status such as disease prevalence (i.e., Wu et al., 2013). Life Space was measured by the Life Space Questionnaire [Stalvey et al., 1999; $\kappa = 0.80$ (as cited by Stalvey et al., 1999)], wherein participants answer nine questions related to their mobility during the past 3 days (e.g., travel, getting out and about on a daily basis to places such as immediate neighborhood or town). Each item is rated "yes/no" and a score is computed by summing across the items. A higher score indicates greater mobility. Life Engagement was measured by the Life Engagement Test (Scheier et al., 2006; $\alpha = 0.77$), a six-item scale, which measures that extent to which a person engages in activities that are personally valued. A lower score indicates

higher engagement. We created a variable to indicate functional disabilities by summing responses to a question regarding activity limitations (e.g., bathing, stair climbing, walking, engaging in sports activities) due to health (range 0–10). We created a variable to indicate health conditions by summing responses to a question regarding the presence of a health condition (e.g., diabetes, arthritis, hypertension) (range = 0–11). Cognition was measured by a latent construct (see section "Results") comprised of a measure of processing speed [Digits Symbol Substitution, Weschler, 1981; α = 0.96 (as reported in Lövdén et al., 2005)], reasoning [Letter Sets, Ekstrom et al., 1976; α = 0.77 (as reported in Ekstrom et al., 1976)], and attention/executive function [Trail Making Test A and B, Reitan, 1958; α = 0.84 (as reported in Dikmen et al., 1999)].

ANALYSIS

For the structural equation models, we used Mplus, which by default handles missing data using full information maximum likelihood and uses all available raw data to estimate missing data for a given case. This approach does well at retrieving correct parameters in simulation (Enders and Bandalos, 2001). Social isolation was assessed using the Friendship Scale and higher scores mean less socially isolated. Model fit statistics are reported using X^2, root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and the standardized root mean residual (SRMR; Kline, 2011).

Each structural equation model included one latent variable for social support, computed by combining the three subscales of the ISEL scale. The model for cognition included a latent variable formed from the Digit Symbol Substitution Test, the Letter Sets Test, and the Trails A test. Trails B was considered for model inclusion but was excluded because it was highly collinear with Trails A. Thus, including both Trails A and Trails B would damage model fit.

We used a path model to examine the extent to which loneliness mediated the relationship between social support, social network size, and social isolation with the dependent variables of depressive symptoms, self-rated health, and latent cognition. We examined whether social support mediated the relationship between social isolation and social network size and depression, health, and cognition. Indirect effects are reported as well as the total indirect effect, which examines if the sum of the indirect paths is statistically significant, and specific indirect effects, where each individual path, is analyzed separately. Significant specific paths are informative even in the absence of a total effect (Rucker et al., 2011).

We then conducted a multiple group analysis of the structural equation model, which involved testing the efficacy of adding increasing levels of equality constraints on the parameters for the younger-older adults and the older-old adults. We started with a model where the groups were allowed to differ on most parameters. Equality constraints were then added to various families of parameters. This allowed us to sequentially test if the means of the variables, the factors loadings, the paths, and the residual errors of the groups differed. The change in X^2 was used to assess model fit. If the change in X^2 was statistically significant when a constraint forcing the two groups to be equal was added, this would suggest the two groups differed on a parameter (e.g., the mean of social support) or on a set of parameters.

RESULTS

Table 1 provides the inter-correlations and descriptive statistics for the variables included in the present analyses. The group means for the older-old (defined as 80+ years) (n = 101) and the younger-old (n = 199) samples as well as univariate contrasts are provided in **Table 2**. We had incomplete data for some of the variables: loneliness (n = 299), health (n = 298), social isolation (n = 299), and social network size (n = 299).

Structural Equation Model of Depressive Symptoms

As shown in the **Table 3**, model fits were generally excellent: $X^2(8) = 11.00$, $p = 0.20$, RMSEA = 0.04 90% CI (0.00, 0.08), CFI = 1.00, TLI = 0.99, and SRMR = 0.02 for the model without age analyzed as a grouping variable. **Figure 1** shows the complete model for depressive symptoms without the age groupings. As shown, those with smaller social networks reported being more socially isolated and having less perceived social support. In turn, greater social isolation and less social support were related to higher degrees of loneliness. Importantly, higher levels of loneliness and greater social isolation independently predicted higher levels of depressive symptoms.

We tested the mediation effects of social network size and social isolation to depressive symptoms through social support and loneliness. There was a significant direct effect of social isolation ($\beta = -0.14$, $z = -3.16$, $p = 0.002$) on depressive symptoms, meaning greater social isolation predicted more depressive symptoms. The indirect effect of social isolation on depressive symptoms through loneliness was significant ($\beta = -0.12$, $z = -3.52$, $p < 0.001$). The path of social isolation to depressive symptoms through social support and then loneliness was also significant ($\beta = -0.08$, $z = -2.99$, $p = 0.003$).

The total indirect effect of social network size ($\beta = -0.026$, $z = -0.80$, $p = 0.43$) on depressive symptoms was not significant. However, the indirect effect of social network size on depressive symptoms mediated through social support and then loneliness was statistically significant ($\beta = -0.05$, $z = -2.51$, $p = 0.01$). Social support had a statistically significant indirect effect on depressive symptoms ($\beta = -0.33$, $z = -3.10$, $p = 0.002$) through loneliness.

Overall, social isolation and loneliness had significant direct effects on depressive symptoms. In addition, the effects of social isolation and social support on depression were mediated by loneliness. Further, those with smaller social networks perceived less social support, which was in turn related to greater loneliness.

Multiple Groups Analysis of Depressive Symptoms

We replicated the previous structural equation model for the two sub-groups of older adults (65–79 and 80–98). **Table 3** presents the full multiple group analyses that tests measurement equivalence between the two groups of older

TABLE 1 | Intercorrelations and descriptive statistics of study variables.

Variable	Mean	1	2	3	4	5	6	7	8	9	10	11	12
1. ISEL appraisal	8.71	2.65											
2. ISEL tangible	8.74	0.56**	2.77										
3. ISEL belonging	7.66	0.54**	0.60**	2.75									
4. Age	76.15	−0.10	−0.05	−0.16**	7.37								
5. Social isolation	19.24	0.50**	0.47**	0.46**	0.07	3.93							
6. Social network size	26.22	0.39**	0.42**	0.39**	−0.06	0.37**	7.39						
7. UCLA loneliness	39.51	−0.54**	−0.57**	−0.62**	−0.01	−0.72**	−0.44**	10.00					
8. Health	3.03	0.16**	0.18**	0.22**	0.02	0.29**	0.18**	−0.35**	0.86				
9. CES-D	11.11	−0.34**	−0.31	−0.33**	−0.08	−0.65**	−0.22**	0.57**	−0.30**	9.03			
10. Digit symbols	34.95	0.08	0.01	0.08	−0.14*	0.07	0.06	−0.06	0.05	−0.002	11.31		
11. Letter sets	8.59	0.04	0.05	0.04	−0.16**	0.07	0.11	−0.09	0.01	−0.08	0.45**	5.23	
12. Trails A	4.02	−0.06	−0.08	−0.11	−0.14*	−0.03	−0.08	0.03	−0.11	−0.02	−0.60**	−0.34**	0.37

Standard deviations are displayed on the diagonal (N = 300).
ISEL, Interpersonal Support Evaluation List; CES-D, Center for Epidemiologic Studies Depression Scale.
$^*p < 0.05$, $^{**}p < 0.01$.

TABLE 2 | Group means and standard deviations for the younger old (65–79) and the older old (80–98) participants (*N* = 300).

	Younger old		Older old		
Variable	**Mean**	**STD**	**Mean**	**STD**	***t*-test**
Age	71.85	4.27	84.62	4.13	24.73**
Health	3.05	0.85	3.00	0.90	−0.47
Depression	11.36	8.86	10.62	9.40	−0.67
ISEL appraisal	8.89	2.56	8.35	2.80	−1.68
ISEL tangible	8.83	2.67	8.55	2.97	−0.83
ISEL belonging	7.94	2.73	7.10	2.70	−2.54*
Social isolation	19.06	4.07	19.59	3.64	1.19
Social network score	26.75	7.05	25.19	7.96	−1.80
UCLA loneliness	39.45	10.01	39.65	10.02	0.07
Digit symbol	35.01	10.73	34.85	12.45	−0.11
Letter sets	8.97	5.12	7.82	5.40	−1.72
Trails A	5.00	0.51	5.08	0.46	0.86

ISEL, Interpersonal Support Evaluation List; CES-D, Center for Epidemiologic Studies Depression Scale.
$^*p < 0.05$, $^{**}p < 0.01$.

adults. If measurement equivalence is not established no latent comparison can be meaningfully made. The constraints tested were path coefficients. We tested the means of the dependent variable of depressive symptoms, the independent variables (social isolation, social network size, and loneliness), and the latent variable of social support, and compared the variances. For depressive symptoms, constraining the latent variable of social support to be equal and constraining depressive symptoms to be equal significantly decreased model fit suggesting the two groups varied significantly on those variables. As more constraints were added such as fixing all paths and variances to be equal, depressive symptoms became equivalent across the two groups. This model with all paths equal, all variances equal, and the independent variables equal showed good model fit $X^2(44) = 68.97$, $p < 0.01$, RMSEA = 0.07, 90% CI (0.04, 0.09), CFI = 0.97, TLI = 0.97, and SRMR = 0.10. Those in older age group had lower social support ($M = -0.47$, $z = 2.43$, $p = 0.02$). In summary, the measurement invariance analysis showed that a model constraining the two groups to be equal, with the exception of the latent variable of social support, had the best model fit.

Structural Equation Model for Health

The model tested for self-ratings of health was the same as for depressive symptoms (**Figure 2**). The model fits were generally excellent: $X^2(8) = 11.46$, $p = 0.18$, RMSEA = 0.04 90% CI (0.00, 0.08), CFI = 1.00, TLI = 0.99, and SRMR = 0.01 (**Table 4**). The interrelationships of social support, social isolation, social network size, and loneliness were identical to those found for depression. Health was predicted only by loneliness with greater loneliness leading to worse self-ratings of health.

Social isolation was not directly related to ratings of health ($\beta = 0.09$, $z = 1.20$, $p = 0.23$). However, there was a significant total indirect effect of social isolation ($\beta = 0.17$, $z = -3.11$, $p = 0.002$) on ratings of health through two paths: (1) through loneliness ($\beta = 0.13$, $z = 2.79$, $p = 0.005$), and (2) through social support and then through loneliness ($\beta = 0.09$, $z = 2.36$, $p = 0.02$). The indirect effect of social isolation to ratings of health

TABLE 3 | Results of structural equation models for depression.

Model	df	X^2	SRMR	RMSEA	TLI	CFI	Δdf	ΔX^2
No age model	8	11.00	0.015	0.035	0.99	0.997		
Multi-group factor analysis								
Model 1. Paths, means (LV, IVs, DV), variances free	20	33.85*	0.044	0.068	0.97	0.99	–	–
Model 1 vs. Model 2	–	–	–	–	–	–	1	7.87**
Model 1 vs. Model 3	–	–	–	–	–	–	3	6.96
Model 2. Paths, means (IVs, DV), variances free	21	41.72**	0.084	0.081	0.96	0.98	–	–
Model 2 vs. Model 4	–	–	–	–	–	–	3	4.34
Model 3. Paths, means (DV, LV), variances free	23	40.81*	0.049	0.072	0.97	0.98	–	–
Model 3 vs. Model 4	–	–	–	–	–	–	1	5.25*
Model 3 vs. Model 5	–	–	–	–	–	–	1	8.29**
Model 3 vs. Model 6	–	–	–	–	–	–	2	13.89**
Model 3 vs. Model 7	–	–	–	–	–	–	10	15.10
Model 4. Paths, means LV, variances free	24	46.06**	0.049	0.078	0.97	0.98	–	–
Model 5. Paths, means DV, variances free	24	49.10**	0.092	0.084	0.96	0.97	–	–
Model 6. Paths variances free	25	54.69**	0.091	0.089	0.95	0.97	–	–
Model 7. Variances, means (DV, LV) free	33	55.90**	0.096	0.068	0.98	0.94	–	–
Model 7 vs. Model 8	–	–	–	–	–	–	8	13.05
Model 8. Means (DV, LV) free	41	68.95**	0.10	0.067	0.97	0.97	–	–
Model 8 vs. Model 9	–	–	–	–	–	–	1	0.02
Model 9. Means (LV) free	*24*	*68.97*	*0.10*	*0.065*	*0.97*	*0.97*	–	–

The first model is without age. The rest of the models are multiple group analyses testing measurement equivalence on different sets of parameters. The best fitting multiple group model as determined by ΔX^2 is in italic.

SRMR, Standardized Root Mean Square Residual; RMSEA, Root Mean Square Error of Approximation; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; Δdf, change in df; ΔX^2, change in X^2; LV, latent variable; IV, Independent Variable; DV, Dependent Variable.

$^*p < 0.05$, $^{**}p < 0.01$.

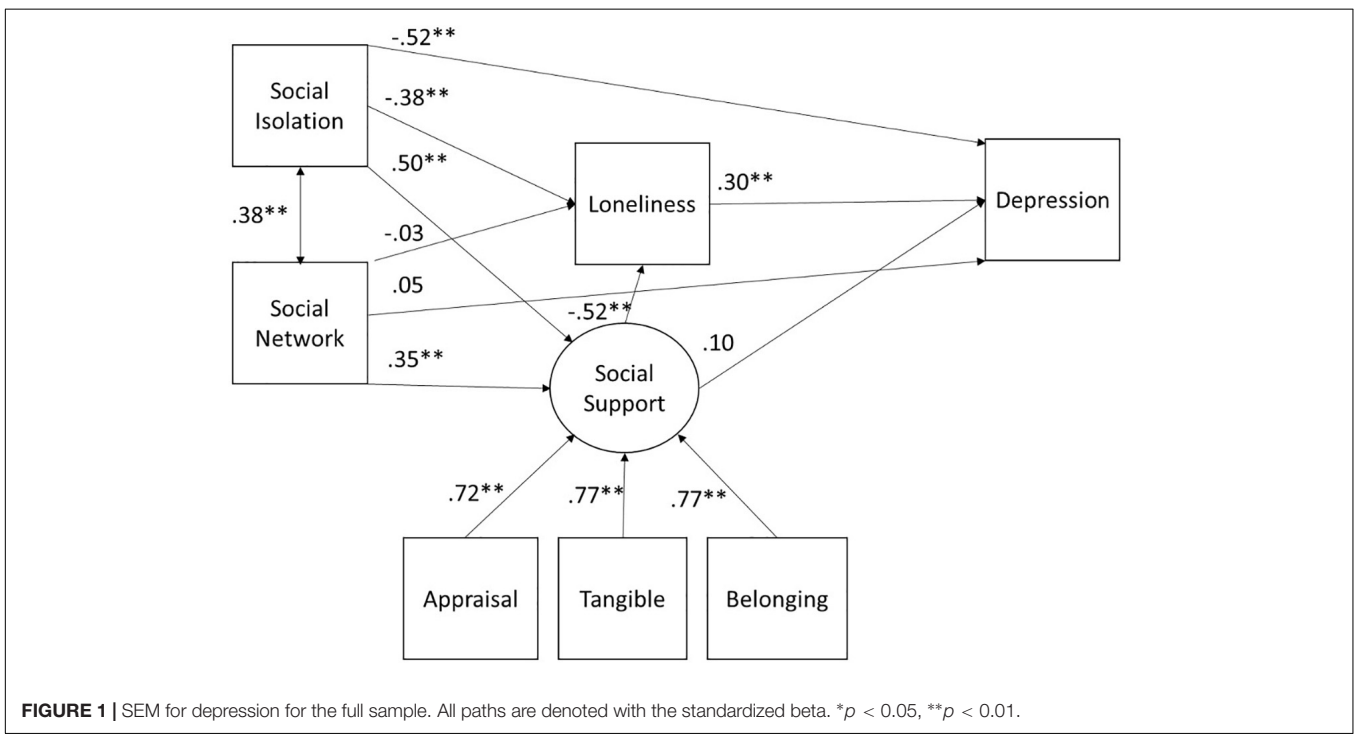

FIGURE 1 | SEM for depression for the full sample. All paths are denoted with the standardized beta. $^*p < 0.05$, $^{**}p < 0.01$.

through social support was not significant (β = −0.05, $z = -0.70$, $p = 0.48$) nor was the total indirect effect of social network size to social isolation (β = 0.04, $z = 0.96$, $p = 0.34$). However, the indirect effect of social network size to self-ratings of health was mediated through social support and then loneliness (β = 0.06, $z = 2.13$, $p = 0.03$). Finally, social support had a significant positive indirect effect on health through loneliness (β = 0.18, $z = 2.55$, $p = 0.01$).

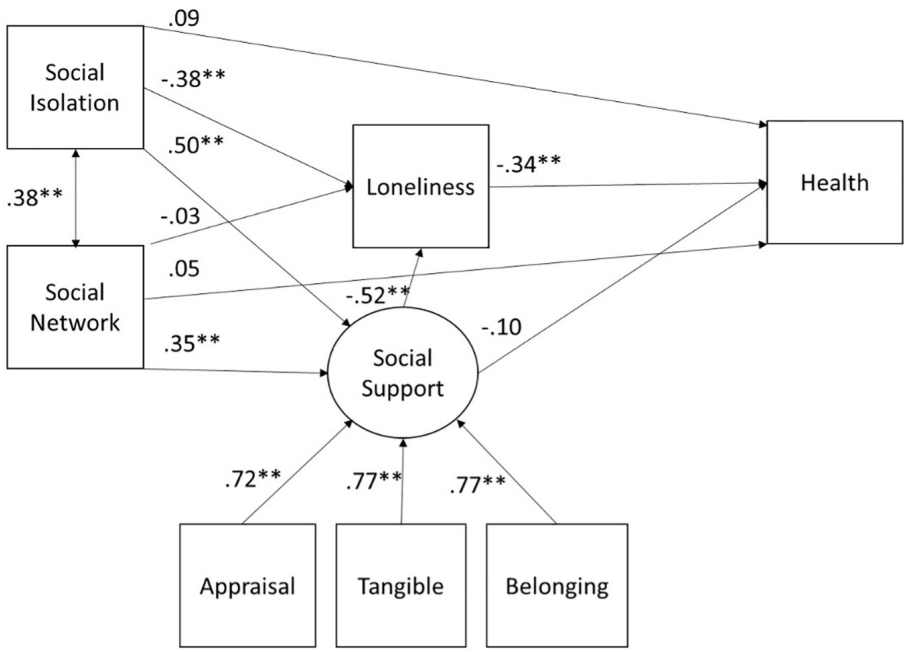

FIGURE 2 | SEM for health for the full sample. All paths are denoted with the standardized beta. *$p < 0.05$, **$p < 0.01$.

TABLE 4 | Results of structural equation models for health.

Model	df	X^2	SRMR	RMSEA	TLI	CFI	Δdf	ΔX^2
No age model	8	11.46	0.014	0.038	0.99	0.998		
Multi-group factor analysis								
Model 1. Paths, means (LV, IV, DV), variances free	20	33.38*	0.043	0.067	0.97	0.98	–	–
Model 1 vs. Model 2	–	–	–	–	–	–	1	7.78**
Model 1 vs. Model 3	–	–	–	–	–	–	3	7.04
Model 2. Paths, means (IVs, DV), variances free	21	41.16**	0.082	0.080	0.95	0.97	–	–
Model 3. Paths, means (LV, DV), variances free	23	40.42*	0.047	0.071	0.96	0.98	–	–
Model 3 vs. Model 4	–	–	–	–	–	–	1	0.58
Model 3 vs. Model 5	–	–	–	–	–	–	1	8.21**
Model 4. Paths, mean LV, variances free	24	41.00*	0.047	0.069	0.96	0.98	–	–
Model 4 vs. Model 6	–	–	–	–	–	–	1	8.21**
Model 4 vs. Model 7	–	–	–	–	–	–	10	9.46
Model 5. Paths, mean DV, variances free	24	48.63**	0.090	0.083	0.95	0.97	–	–
Model 5 vs. Model 6	–	–	–	–	–	–	1	0.58
Model 6. Paths variances free	25	49.21**	0.091	0.080	0.95	0.97	–	–
Model 7. Variances, mean LV, free	34	50.46*	0.094	0.057	0.98	0.98	–	–
Model 7 vs. Model 8	–	–	–	–	–	–	8	13.40
Model *8. Mean LV Free*	*42*	*63.86**	*0.10*	*0.059*	*0.97*	*0.97*	–	–

The first model is without age. The rest of the models are multiple group analyses testing measurement equivalence on different sets of parameters. The best fitting multiple group model as determined by ΔX^2 is in italic.
SRMR, Standardized Root Mean Square Residual; RMSEA, Root Mean Square Error of Approximation; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; Δdf, change in df; ΔX^2, change in X^2; LV, latent variable; IV, Independent Variable; DV, Dependent Variable.
*$p < 0.05$, **$p < 0.01$.*

In summary, those with higher levels of loneliness report worse health. In addition, the effect of social isolation on ratings of health was mediated by loneliness and social support. Further, social network size was significantly related to ratings of health via social support and loneliness.

Multiple Groups Analysis of Health

We replicated the previous analysis with the two subgroups of older adults (aged 65–79 and 80–98). **Table 4** shows model fit for all analyses, as with depression, the Table compares measurement equivalence with different levels of strictness criteria to establish

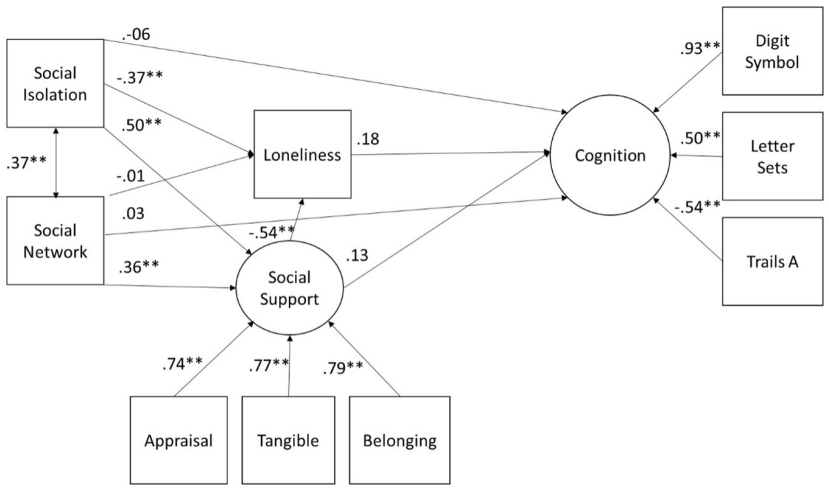

FIGURE 3 | SEM for latent Cognition for the full sample. All paths are denoted with the standardized beta. *$p < 0.05$, **$p < 0.01$.

both that the groups are comparable in terms of the structure of the model and what differences in levels exist. For ratings of health constraining the latent variable to be equal, significantly decreased model fit suggesting the two groups varied on the latent variable of social support. The model allowing the two groups to have different means for social support showed good fit $X^2(44) = 63.86$, $p = 0.02$, RMSEA = 0.06, 90% CI (0.03, 0.09), CFI = 0.97, TLI = 0.97, and SRMR = 0.10. As observed for depression, the older group had lower scores on the latent social support variable ($M = -0.46$, $z = 2.43$, $p = 0.02$).

Structural Equation Model for Cognition

The model tested for cognition was the same as for depressive symptoms and health (**Figure 3**). Model fit was excellent [$X^2(20) = 25.91$, $p = 0.17$, RMSEA = 0.03 90% CI (0.00, 0.06), CFI = 0.99, TLI = 0.99, and SRMR = 0.03]. The interrelationships of social support, social isolation, social network size, and loneliness were identical to those found for depression. Cognition was not significantly predicted by any of the social variables and there were no significant indirect effects.

Multiple Groups Analysis of Cognition

We replicated the previous analysis with the two subgroups of older adults (aged 65–79 and 80–98). **Table 5** shows model fit for all analyses conducted to establish to what degree the groups are equivalent and sources of differences should they exist. For ratings of cognition, constraining the latent variable of social support to be equal, significantly decreased model fit suggesting the two groups varied on the latent variable of social support; however, this was not the case for the latent variable of cognition. As observed for depressive symptoms and health, the older group had lower social support ($M = -0.47$, $z = 2.59$, $p = 0.01$). The best fitting model indicated the paths to depressive symptoms to be significantly different between the two groups. This model showed good fit [$X^2(69) = 93.37$, $p = 0.03$, and RMSEA = 0.049 90% CI (0.02, 0.07), CFI = 0.97, TLI = 0.97 and SRMR = 0.14] (see **Table 5** for complete results). Probing the paths to cognition showed that the paths from social network size and [$X^2(1) = 3.98$, $p = 0.03$], and social isolation [$X^2(1) = 6.81$, $p = 0.01$] were significantly different between the two age groups if tested separately or together [$X^2(2) = 10.94$, $p = 0.004$]. However, the parameter estimates for the individual group paths for social isolation and cognition were not significant for the younger group, ($b = 0.29$, $z = 1.02$, $p = 0.31$ or the older, $b = -0.49$, $z = -1.43$, $p = 0.15$). For social network size the effect was significant for the older group ($b = 0.41$, $z = 2.27$, $p = 0.02$), but not significant for the younger group ($b = 0.04$, $z = -0.63$, $p = 0.53$). For the older group a having a larger social network was related to higher cognition.

Multiple Regressions Predicting Loneliness and Social Isolation

As loneliness and social isolation were pivotal variables in our model, we decided to more thoroughly test the factors that predicted both constructs. Guided by the WHO's international Classification of Function, Disability, and Health (ICF; World Health Organization, 2002) model, we included three sets of potential predictors, personal factors (age, gender, income, education, and race), environmental factors (life space, social network size, and life engagement), and health (reported number of functional limitations, and number of reported health conditions) on the sample of 253 participants for whom we had complete data. We eliminated 13 participants as they identified their race/ethnicity as other than White, Hispanic, or African American (e.g., Asian, Mixed Race) and there were too few participants in the other categories for meaningful comparisons. To confirm that each of these sets were important we ran sequential hierarchical multiple regressions (**Table 6**).

The full model for loneliness was strongly significant $F(10,242) = 20.23$, $p < 0.001$, $R^2 = 0.46$. The step entering personal factors explained the least variance and was not

TABLE 5 | Results of structural equation models for cognition.

Model	df	X^2	SRMR	RMSEA	TLI	CFI	Δdf	ΔX^2
No age model	20	23.15	0.021	0.023	0.994	0.997		
Multi-group factor analysis								
Model 1. Paths, means (LV, IV, DV), variances free	48	61.33	0.051	0.043	0.98	0.99	–	–
Model 1 vs. Model 2	–	–	–	–	–	–	1	7.70**
Model 1 vs. Model 3	–	–	–	–	–	–	3	7.00
Model 2. Paths, means (IVs, DV), variances free	49	69.03*	0.076	0.052	0.97	0.98	–	–
Model 3. Paths, means (LV, DV), variances free	51	68.33	0.055	0.048	0.98	0.98	–	–
Model 3 vs. Model 4	–	–	–	–	–	–	1	0.14
Model 3 vs. Model 5	–	–	–	–	–	–	1	8.15**
Model 4. Paths, mean LV, variances free	52	68.47	0.055	0.046	0.98	0.98	–	–
Model 4 vs. Model 6	–	–	–	–	–	–	1	8.06**
Model 4 vs. Model 7	–	–	–	–	–	–	10	19.21**
Model 4 vs. Model 8	–	–	–	–	–	–	11	16.45
Model 5. Paths, mean DV, variances free	52	76.48*	0.083	0.056	0.97	0.97	–	–
Model 5 vs. Model 6	–	–	–	–	–	–	1	0.05
Model 6. Paths, variances free	53	76.53*	0.083	0.054	0.97	0.98	–	–
Model 7. Variances, mean LV, free	62	87.68*	0.091	0.053	0.97	0.97	–	–
Model 8. Paths, mean LV free	63	84.92*	0.133	0.048	0.97	0.98	–	–
Model 8 vs. Model 9	–	–	–	–	–	–	10	19.60**
Model 8 vs. Model 10	–	–	–	–	–	–	6	8.44
Model 9. Mean LV free	73	104.52**	0.127	0.054	0.97	0.97	–	–
Model 10. Cognitive paths, mean LV free	69	93.362*	0.14	0.05	0.97	0.97	–	–

The first model is without age. The rest of the models are multiple group analyses testing measurement equivalence on different sets of parameters. The best fitting multiple group model as determined by ΔX^2 is in italic.

SRMR, Standardized Root Mean Square Residual; RMSEA, Root Mean Square Error of Approximation; TLI, Tucker-Lewis Index; CFI, Comparative Fit Index; Δdf, change in df; ΔX^2, change in X^2; LV, latent variable; IV, Independent Variable; DV, Dependent Variable in this case latent cognition.

$^*p < 0.05$, $^{**}p < 0.01$.

statistically significant [$F(5,247) = 1.33$, $p = 0.25$, $R^2 = 0.03$], and thus we do not discuss individual parameters (see **Table 7**). In the second step, we entered the health variables and this step was strongly statistically significant [$F(2,245) = 19.18$, $p < 0.001$, $\Delta R^2 = 0.13$]. The only significant variable was functional limitations; having more limitations was associated with higher degrees of loneliness [$t(245) = 4.23$, $p < 0.001$, $f^2 = 0.07$]. In the third step, we entered the environmental variables and this step also explained a great deal of variance $F(3,242) = 44.02$, $p < 0.001$, $\Delta R^2 = 0.30$. Having a larger social network was associated with less loneliness [$t(242) = -4.85$, $p < 0.001, f^2 = 0.10$], and higher reporting of engaging in valued activities was also associated with less loneliness [$t(242) = -8.34$, $p < 0.001, f^2 = 0.29$].

The full model for social isolation was also strongly significant [$F(10,242) = 12.53$, $p < 0.001$, $R^2 = 0.34$]. The step entering personal factors explained the least variance and was not statistically significant [$F(5,247) = 1.42$, $p = 0.22$, $R^2 = 0.03$], thus we do not discuss individual parameters (see **Table 8**). In the second step, we entered the health variables and this step was strongly significant [$F(2,245) = 8.91$, $p < 0.001$, $\Delta R^2 = 0.07$]. Having more functional limitations with more limitations was associated with greater social isolation [$t(245) = -2.76, p < 0.001$, $f^2 = 0.03$]. In the third step, we entered the environmental variables and this step also explained a great deal of variance [$F(3,242) = 30.25$, $p < 0.001$, $\Delta R^2 = 0.25$] in social isolation. Again, having a large social network was associated with less loneliness [$t(242) = 3.56$, $p < 0.001$, $f^2 = 0.05$], as did higher reporting of engaging in valued activities [$t(242) = 7.05$, $p < 0.001, f^2 = 0.21$].

DISCUSSION

The aging of the population generates a pressing need to develop strategies to ensure that current and future cohorts of older people are able to live as independently as possible and enjoy a good quality of life. Recently, increased attention is being directed toward social isolation and loneliness among older people, as being isolated and lonely has a deleterious impact on physical, emotional, and cognitive health. Current data indicate that a large proportion of the aging population is socially isolated and lonely (e.g., Anderson and Thayer, 2018; Cudjoe et al., 2020). Strategies to prevent or remediate social isolation and loneliness are predicated on understanding factors that are related to being socially isolation and lonely. This is a complex issue as social engagement has many components, which are correlated but distinct.

In this study we had the unique opportunity to examine the relationships among a number of constructs related to loneliness and social isolation among a diverse sample of older adults living alone in the community. We explored the relationships between

TABLE 6 | Descriptive statistics for hierarchical variables included in the multiple regression analyses (N = 253).

Variable	Statistic
	M (SD)
Loneliness	39.3 (9.7)
Friendship	19.3 (7.4)
Age	75.7 (7.4)
Functional limitations	5.6 (3.2)
Health conditions	3.3 (1.7)
Life space	5.7 (1.5)
Social network size	26.4 (7.3)
Life engagement	24.9 (4.0)
Functional limitations	5.6 (3.2)
Health conditions	3.3 (1.7)
	n (%)
Gender	
Female	196 (76.7%)
Male	59 (23.3%)
Income	
<$30000	218 (86.2%)
$30000-$59999	31 (12.2%)
>$59999	4 (1.6%)
Race	
African-American	92 (36.4%)
Hispanic	26 (10.3%)
White	135 (53.3%)

loneliness and isolation on depressive symptoms, health, and cognitive outcomes. Our sample included both younger-old and older-old individuals thus we could explore if these relationships varied according to these subgroups of older people. Our findings help to clarify the relationships among the various aspects of social support, isolation, and loneliness, as well as the resultant impacts on both mental health, physical health, and cognition. Further, we evaluated personal, environmental, and health factors that are associated with isolation and loneliness.

Consistent with models of successful aging (e.g., Rowe and Kahn, 1988; Kahana and Kahana, 1996, 2001), our findings indicated that social engagement is an important aspect of what it means to age successfully. Overall, the results underscored the findings of other investigators (e.g., Cacioppo et al., 2010; Aylaz et al., 2012; Valtorta et al., 2016; Hakulinen et al., 2018; Jeuring et al., 2018; Domenech-Abella et al., 2019; Read et al., 2020), that loneliness and social isolation have a significant impact on emotional well-being and health. Loneliness is particularly deleterious as it has a direct impact on both emotional and physical health. People who were lonely were more likely to report depressive symptoms and rated their health as worse than those who were not lonely. This has important implications for older adults and society as a whole. The economic burden of depression in the United States is about $210 billion annually, which includes costs associated with the treatment of depression itself as well as associated co-morbidities. In addition, those who reported that they had limitations engaging in meaningful activities and those with more functional limitations reported greater loneliness.

Our results showed that that loneliness was significantly related to symptoms of depression. There was also a significant direct path between social isolation and depressive symptoms. These findings suggest that isolation and loneliness are related but distinct constructs. Not surprisingly, social isolation was predicted by social network size. Social network size and social isolation were also related to social support, which in turn was related to loneliness. In general, older adults with larger social networks were less likely to be isolated and had greater perceived social support. They were also less likely to be lonely. Our findings showed that among the older adults, social network size was also related to cognition such that people in the older cohort with larger social networks scored higher on the composite measure of cognition. As noted, having a larger social network likely provided more opportunities for engagement and support. Alternatively, maintaining a social network may require a certain amount of cognition and individuals with higher levels of cognitive function may be better able to maintain those relationships. Others have found that size of one's social network is also related to access to resources (e.g., Cannuscio et al., 2003). The majority of individuals in our sample were in the lower socio-economic strata.

With respect to self-ratings of health, we found slightly different relationships. Specifically, loneliness had a direct negative impact on health but the relationship between social isolation and ratings of health was mediated by loneliness and social support. Although our study was limited to a subjective rating of health, others (i.e., Wu et al., 2013) have found that self-ratings of health are predictive of objective indices of health and mortality. Thus, our findings underscore the importance of social engagement to health and well-being.

We did not find differences in the relationships among the variables for depressive symptoms or ratings of health between the younger-old and older-old adults. However, we did find that perceived social support was lower among the older-old people in our sample. This is important given the increasing number of people in this cohort and the relationship between social support and loneliness. People in the older age cohorts, especially older women are more likely to live alone and have fewer sources of support available due to changes in life circumstances.

The findings from our regression analyses also point to the associations among individual and environmental variables and social isolation and loneliness. We found, not surprisingly that individuals with more functional limitations and those who less engaged in rewarding activities reported higher levels of loneliness. It is likely that functional limitations result in logistic hindrances to activity engagement.

Our findings have important implications for the design of interventions. Strategies to increase the social networks older adults, enhance social support, and the ability to engage in meaningful and enjoying activities would likely be beneficial in terms of improving health outcomes, especially for those with functional limitations. These interventions might include creating affordable programs for older adults and connecting individuals to these programs or venues for peer support. It

TABLE 7 | Results of hierarchical regression predicting loneliness.

	B	SEM	*p*	f^2	R^2	ΔR^2
Personal					0.03	
Age	0.07	0.09	0.45	<0.01		
Gender	−2.07	1.48	0.16	0.01		
Income	−0.56	0.37	0.13	0.01		
Hispanic	1.79	2.16	0.41	<0.01		
African-American	−1.69	1.50	0.26	<0.01		
Health					0.16**	0.03**
Functional limitations	0.89	0.21	<0.001**	0.07		
Health conditions	0.81	0.39	0.92	0.02		
Environment					0.46**	0.30**
Life space	−0.43	0.34	0.21	0.01		
Social network size	−0.35	0.07	<0.001**	0.10		
Life engagement	−1.03	0.12	<0.001**	0.29		

The row in gray represents a set of variables with R^2 being the variance explained by all variables in the model at the step and ΔR^2 being the change in variance explained by the set of variables added in the step. Parameter estimates are for the step.
B, Unstandardized Beta; SEM, Standard error of measurement; f^2, Cohen's f^2 a measure of effect size representing the signal to noise ratio.
**p < 0.05; **p < .01.*

TABLE 8 | Results of hierarchical regression predicting social isolation.

	B	SEM	*p*	f^2	R^2	ΔR^2
Personal					0.03	
Age	0.02	0.04	0.65	<0.01		
Gender	0.86	0.57	0.13	0.01		
Income	0.25	0.14	0.08	0.01		
Hispanic	−0.17	0.83	0.84	<0.01		
African-American	0.80	0.58	0.17	0.01		
Health					0.09**	0.07**
Functional limitations	−0.23	0.08	0.01**	0.03		
Health conditions	−0.24	0.15	0.12	<0.01		
Environment					0.34**	0.25**
Life space	0.20	0.16	0.20	0.01		
Social network size	0.17	0.03	<0.001**	0.05		
Life engagement	−1.03	0.12	<0.001**	0.21		

The row in gray represents a set of variables with R^2 being the variance explained by all variables in the model at the step and ΔR^2 being the change in variance explained by the set of variables added in the step.
B, Unstandardized Beta; SEM, Standard error of measurement; f^2, Cohen's f^2 a measure of effect size representing the signal to noise ratio.
**p < 0.05, **p < 0.01.*

might also involve facilitating access to transportation services and enhancing community safety.

Information and communication technologies offer vast potential in terms of promoting social engagement (Bixter et al., 2018). For example, social media platforms such as Facebook and LinkedIn, offer opportunities to make new friends and share information about life events with friends and family thus promoting connectivity and a sense of belonging. Data from the Pew Research Center (Anderson and Perrin, 2017) indicate that older adults are increasingly using social media platforms to share their experiences and connect with friends and family (see also Bixter et al., 2019). Video chat platforms provide an additional avenue for social communication and cognitive enrichment (e.g., Nie et al., 2020) as well as physical activity (Beer et al., 2015).

Access to the Internet and email can also foster social connectivity. Findings from the PRISM trial (Czaja et al., 2018) found that use of the PRISM software system resulted in decreased loneliness among older people. One of the most used PRISM features was the internet and one of the reported benefits of PRISMs was the ability to communicate with families and friends. Others have also found that having access to the Internet benefits social engagement (e.g., Cotten et al., 2013; Morris et al., 2014). A recent study (Wu, 2020) found that internet use was associated with decreased loneliness over an 8-year period as it was a vehicle for maintaining social contact.

Virtual reality (VR) applications are increasingly being targeted toward older adults and provide a mechanism for interacting with others in an individual or group format as well as engaging in valuable activities. For example, one can engage

in virtual travel or cultural events using a VR system. As noted, our data indicate that lack of engagement in valued activities is related to both social isolation and loneliness. These applications may also be especially beneficial for those with functional limitations who may have mobility restrictions. Design recommendations for VR systems targeted to older adults are being developed (e.g., McGlynn and Rogers, 2017). Developments in robotics are being geared toward enhancing social interactions among older adults (Rogers and Mitzner, 2017).

However, although technology holds great potential in terms of fostering social interactions and decreasing loneliness among older adults it is important that technology applications are designed using a user-centered design approach where diverse and representative samples of older adult users are involved in the design process. This approach helps to ensure that the needs, preferences, and characteristics of aging adults are incorporated into the design of the technology application. Aging adults must be aware of technology developments and how various technology applications may improve their well-being and quality of life. Technology must be affordable and instructional and technical support must be available. Finally, technology cannot replace human contact, it provides a complementary vehicle for social interaction.

Importantly, simply increasing social networks and social engagement is not sufficient for decreasing loneliness. The networks and engagement must be satisfying and result in enhanced feelings of support. Activities must also be rewarding and engaging. Finally, it is important to recognize that there is no one-size-fits-all approach to addressing loneliness or social isolation, and tailor interventions should be tailored to the needs, preferences, and contexts of individuals.

Limitations of this study include the use of a self-report single item measure of health. Although this measure is commonly used and has been found to be related to objective health metrics. In addition, the data were cross-sectional and from a single time point which reduces the ability to make causal inferences. Our sample was largely of lower socio-economic status and restricted to individuals who lived alone in the community. Further, our sample was a convenience sample, that agreed to participate in a research trial. Thus, the findings may not generalize to other subpopulations of older adults. Finally, although path models are useful in conceptualizing interrelationships among variables of interest, these models only present associations and do not prove causal relationships. Despite these limitations the present study adds to the growing body of literature examining the important role of social engagement in promoting health and well-being among older people. It clearly demonstrated associations and pathways among social isolation, social support, and loneliness. We recognize of course that these relationships may be bi-directional or in the opposite direction hypothesize, for example that social isolation may be affected by health, which underscores the complexity of these relationships. Nonetheless, these data provide valuable guidance for the development of interventions to both prevent isolation and loneliness among those who are at risk and remediate these problems for those who are currently isolated and lonely. The findings also underscore the importance of directing attention to the public health risk of social isolation and loneliness especially in light of the COVID-19 pandemic.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Miller School of Medicine IRB. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SC and WR designed the study that is the source of the article. SC drafted the manuscript. JM designed the analysis, conducted and written in consultation with SC. All authors contributed to editing the article.

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Voice-Activated Virtual Home Assistant Use and Social Isolation and Loneliness Among Older Adults: Mini Review

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A lack of social connectedness is common among older adults due to living alone, loss of loved ones, reduced mobility, and, more recently, social distancing created by the global Covid-19 pandemic. Older adults are vulnerable to social isolation and loneliness, which pose significant health risks comparable to those of smoking, obesity, physical inactivity, and high blood pressure. A lack of social connectedness is also correlated with higher mortality rates even when controlling for other factors such as age and comorbid conditions. The purpose of this mini review was to explore the emerging concepts of older adults' use of commercially available artificial intelligent virtual home assistants (VHAs; e.g., Amazon Echo, Google Nest), and its relationship to social isolation and loneliness. A secondary purpose was to identify potential areas for further research. Results suggest that VHAs are perceived by many older adult users as "companions" and improve social connectedness and reduce loneliness. Available studies are exploratory and descriptive and have limited generalizability due to small sample sizes, however, similar results were reported across several studies conducted in differing countries. Privacy concerns and other ethical issues and costs associated with VHA use were identified as potential risks to older adults' VHA adoption and use. Older adults who were using VHAs expressed the need and desire for more structured training on device use. Future research with stronger methods, including prospective, longitudinal, and randomized study designs are needed. Public education, industry standards, and regulatory oversight is required to mitigate potential risks associated with VHA use.

Keywords: virtual home assistant, conversational assistant, voice-activated speaker, social connectedness, social isolation, loneliness, older adults, geriatric (aging)

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INTRODUCTION

Social isolation and loneliness are serious public health concerns that affect a significant portion of the older adult population. The National Health and Aging Trends Study indicated that 24% of all community-dwelling adults aged 65 and older in the United States (US) were socially isolated (1). The National Health and Retirement Study revealed that 43% of US adults aged 60 and older report loneliness (2). Authors of a study in Germany, reported 30% of the participants expressed feeling lonely 1–3 times per month (3). Older adults are often at risk for social isolation and loneliness

due to factors such as living alone, loss of loved ones, reduced mobility, vision, and hearing deficits, and, recently, the necessity for social distancing due to the Covid-19 pandemic (4). Social disconnectedness is correlated with higher mortality rates even when controlling for other factors such as age and comorbid conditions. Meta-analysis findings revealed social isolation and loneliness elevate mortality risk by 26–32%, similar in magnitude to that of established risk factors, such as smoking, obesity, physical inactivity, and high blood pressure (5). Social isolation or loneliness in older adults has also been associated with a 50% increased risk of dementia (6) and a 30% increased risk of coronary artery disease (7).

Social connection describes the structural, functional, and quality aspects of human relationships and interactions (8). Social isolation is the objective lack or limited extent of social connection with others. Loneliness is the subjective feeling of being lonely. Socially isolated people may not feel lonely, and, contrarily, persons with many social connections may express loneliness (9). Typically, social support functions to provide emotional, tangible, informational, and/or companionship assistance to improve social connection (8). Unfortunately, traditional social supports may not always be available. Although many social support interventions have been implemented in community organizations, participation by older adults may be limited by access, cost, mobility, and/or interest (8). The emergence of artificial intelligence (AI) may offer unprecedented opportunities to relieve social isolation and loneliness among older adults to improve health outcomes.

Artificial intelligence describes algorithms that emulate human cognitive and behavioral processes and are installed into software programs of various platforms connected to the internet (10). Conversational agents are one such platform, whereby a device automatically processes and responds to human voice and language. Through natural language processing and machine learning, conversational agents interpret questions and respond with messages using a simulated human tone (11). With increased online data availability and technological advances, commercially available VHAs have been marketed by companies such as Amazon (i.e., Echo/"Alexa") and Google (i.e., Google Nest) for about 6 years. Commercially available voice-activated virtual home assistants (VHAs) are relatively inexpensive and may be particularly useful for older adults who have less technological literacy or vision or fine motor limitations.

Virtual home assistant users can listen to music, ask for information, and set reminders (12). Virtual home assistants also offer a range of applications or "skills" to engage users, such as games, that could serve as cognitive stimulation (13), mood enhancement (14), and relief from boredom (15). In addition to these common uses, VHAs offer a promising technology to provide social connectivity through video calling and surrogate companionship in a manner that addresses social isolation and helps relieve loneliness. The purpose of this mini review was to explore research findings on older adults' VHA use and its potential relationship to social isolation and loneliness.

TABLE 1 | Concepts with MeSH and TIAB terms used for PubMed search.

Construct/ concept	Mesh term	TIAB term
Voice-activated virtual home assistant	Ambient (sensors), artificial intelligence, deep learning, voice[–]activated virtual assistants, **conversational agents**, social support agents	Alexa, Google Home, Google Nest, Amazon Echo, digital assistant, virtual assistant, voice activated assistant, VHA
Social isolation	Isolation, social (use this word to find terms similar to "social isolation"), social exclusion, social alienation	COVID, social isolation, loneliness, social exclusion, social connectedness
Loneliness	Loneliness, depression, geriatric psychiatry	Social connectedness
Older adults	Older adults, gerontology, geriatrics	Grandparents, elderly, aging in place

MATERIALS AND METHODS

Data Sources

A mini review was conducted to identify the current state of the science on older adults' VHA use and its potential relationship to social isolation and loneliness. Specific search terms were created for social isolation, loneliness, and older adults. However, as relatively new devices, no common electronic database terms for VHAs were identified. Thus, a variety of terms, including voice assistants, virtual assistants, and conversational agents were used in the searches. The search strategy was based on the recommended practice of each selected electronic database (PubMed, CINAHL, PsycInfo, Compendex) using a combination of sililar terms (**Table 1**).

Data Selection and Extraction

Articles were deemed eligible for review if they were published in a peer-reviewed journal, written in English, addressed a concept related to social isolation or loneliness, and involved older adults' use of a commercially available VHA. Each eligible article was independently appraised based on inclusion and exclusion criteria by our team. Following title and abstract, the search yielded only four articles, and none were retained following full article review. Thus, the articles evaluated in this mini review were gleaned from the authors' reference libraries ($n = 6$) and article reference searches ($n = 1$).

RESULTS

Study Characteristics

Study designs of the research included in this mini review were descriptive and used convenience samples. Except for one study (3), findings are based on qualitative content analysis. Of the seven studies, five used prospective methods and two were retrospective analyses of publicly available consumer reviews of VHAs (**Table 2**). The five prospective descriptive studies enrolled older adults who had not previously used VHAs and had small sample sizes. One study reported findings from 30 participants;

TABLE 2 | VHA study characteristics.

Primary Author, Year	Study design	Sample	Participant ages	Study duration	Device
Chambers, 2020	Prospective	$n = 30$ adults with chronic health conditions	Not reported	≥2 months	Echo Show
Chung, 2021	Retrospective	$n = 320$ consumer reviews from verified buyers, 2018	Not reported	N/A	Xiaomi XiaoAI
Corbett, 2021	Prospective	$n = 19$	Older adults ($n = 10$) 70 and older (X = 75); support persons ($n = 9$), (X = 53);	4 months	Echo Show and Dot (older adults), Echo Spot (support persons)
Kim, 2021	Prospective	$n = 12$	77–95 years	4 months	Google Home
O'Brien, 2020	Retrospective	$n = 125$ consumer reviews, 2015–2018	Not reported	N/A	Amazon Echo
Pradhan, 2019	Prospective	$n = 7$	65–83 years	3 weeks	Echo Dot
Scherr, 2020	Prospective	$n = 11$	68–83 years	≥12 months	Echo Show

Chambers and Beaney (15); Chung and Woo (16); Corbett et al. (12); Kim and Choudhury (17); O'Brien et al. (13); Pradhan et al. (18); Scherr et al. (3).

however, not all participants were older adults (3). Another study included older adults ($n = 10$) and their respective support persons ($n = 9$) (12). All other sample sizes in the prospective studies included 7–12 older adult participants (aged 65–95 years). Study duration ranged from 3 weeks to 18 months. Amazon devices were used in four and Google devices in one of the prospective studies. The secondary analyses of consumer reviews reported user findings from Amazon Echo devices (13) and from Xiaomi XiaoAI, a VHA available in China (16).

Social Isolation and Loneliness

Companionship was reported as a benefit for older adult VHA users in both consumer review studies. O'Brien et al.'s analysis of VHA consumer reviews was specific to older adults and companionship was one of five identified themes (13). Supporting quotes from the consumer reviews included: *Echo now keeps me company and allows me to keep my brain active too. She is more than a great bit of electronics. . . .she is also a companion for me.* Chung and Woo's study analyzed comments from consumers of Xiaomi XiaoAI, were not specific to older adults (16). However, one theme noted by the investigators was the potential for VHA use to decrease loneliness and social isolation among older adult users, supported by the following consumer review: *Having her [Xiaomi XiaoAI], I am no longer lonely.*

The prospective studies ($n = 5$) identified companionship as a major finding. Chambers and Beaney's study provided VHAs to people who had health or dependence needs, of whom some were older adults (15). They reported that the participants who lived alone or were solitary for most of the day characterized the VHA as a source of companionship that reduced loneliness and improved mental health. Pradhan et al. conducted semi-structured interviews with older adult participants prior to installing the VHA devices in their homes and, after installation, conducted follow-up interviews every week for 3 weeks (18). One of their thematic findings was that the natural language processing and responsiveness of the VHA resulted in older adults perceiving the VHA as a friend. Supporting quotes included:

> *. . . .when it talks, I don't see a box. I just see. . . .It's like somebody is standing there talking to me. . . .Somebody is here with me and they're having a conversation with me. It's making my day.* [(18), p. 2].
> *. . . And it answers me and I am talking to it, I could think of it as a person.* [(18), p. 5].

Studies conducted by Corbett et al. (12) and Kim and Choudhury (17) placed VHAs in older adults' homes for 4 months. Kim and Choudhury interviewed participants every other week during the study whereas Corbett et al. interviewed participants once at the end of the 4-month study. Similar findings about companionship were obtained from each study as exemplified below.

> *I have humanized that machine. I call her a 'she' and a 'her' and every morning I say,*
> *'Alexa what is the weather going to be like?' . . . .I always report in every morning and every night and I just have a kinship with Alexa. . . . And you know, I know that's a machine. . . [laughs] but it's just that I feel like it's somebody here with me.* [(12), p. OA105].
> "*I think it is really good. It's not as if you're talking to yourself. You're talking to somebody. It makes you feel like you're really not alone. You never have to be alone because you can talk to Google*". [(17), p. P8W8].

Authors of another study summarized the overall results from their study in a similar manner noting that Alexa had "*become a beloved new roommate*" for their participants. "Even though everyone knows that device is just a machine that can speak, for some of the participants it feels like an actual person that can reduce loneliness" [(3), p. 8].

Scherr et al. quantitatively measured loneliness and social isolation among their participants ($n = 11$) who were enrolled at least 12 months and lived within a defined neighborhood (3). Both individual and group interviews of participants were

conducted. Group interviews allowed participants to interact with one another in person and exchange ideas about using the VHA. Every 3 months participants rated how often they felt lonely with response items that ranged from never to daily. Results indicated that participants reported reduced loneliness over time and reported increased social connectedness by using the VHA for video calling feature several times per week.

DISCUSSION

Main Findings

The purpose of this mini review was to synthesize knowledge about the potential relationship between older adults' VHA use and the influence on social isolation and loneliness. The research findings were primarily based on qualitative content analysis. Quotes from several of the studies supported that the VHA reduced loneliness in many participants. Based on the findings of their study, Pradhan et al.'s suggested participants' interactions with the VHA reduced loneliness in the moment rather than alleviating a more global feeling of loneliness (18). However, Scherr et al. specifically measured both loneliness and social connectedness and reported participants improved in both areas over time (3).

All researchers in this mini review noted that the VHA provided a source of companionship for the users. "Companionship" is defined in the Meriam-Webster dictionary as "the good feeling that comes from being with someone else" (19) and "companion" is defined as "a person or animal you spend time with or enjoy being with…sometimes used figuratively" (20). The exemplar quotes reflected that the human-sounding voice and the conversational qualities of a Virtual home assistant lead users to personify the VHA and view it as a companion. Similar findings were documented in other VHA literature (21–24). Rubin et al. suggested that VHAs are inherently socially interactive because verbal prompting is required to activate the device (25). Other researchers reported that people in households of one or two people use VHAs more than those in larger households and attributed this finding to the social aspects of VHA use (26). Device placement in the home was also noted as important. The VHA may provide a human-like "presence" when the user is in the same room, but the feeling is reduced when the user is separated from the device (18).

To better understand VHA users' behavior, Han and Yang tested whether users may develop parasocial relationships with their VHAs (27). Parasocial relationship theory was originally used to explain people's imaginary interpersonal relationships between themselves and media (e.g., radio, television) personalities. Han and Yang measured the three parasocial relationship concepts of task attraction (how easy or worthwhile the device is to use and its reliability to complete a task), physical attraction (the user's perception of the visual appearance of the VHA), and social attraction (the user's intention to communicate and make friends with the VHA) in a sample of younger VHA users ($n = 304$). Users' social attraction to the VHA had four-fold greater impact on developing a positive parasocial relationship with the VHA than task attraction or physical attraction (27). Thus, their findings reinforce the importance of the human-like qualities of VHAs and provide insight into how people may develop the perception of the VHA as a companion, which may reduce loneliness.

Virtual home assistant capabilities that may reduce social isolation include providing information on news and current events, streaming religious services, and allowing voice and video calls to socially connect. Scherr et al. reported that many of their participants used the VHA at least several times per week for video calls (3). However, studies involving video calls to residents in long- term care facilities were inconclusive about the effect on social connectedness (28). Results of several studies in this mini review reported that participants liked the ease of using VHAs as compared to other technology, such as a mobile phone or computer (3, 12, 17), but also noted that older adult users desired more education and training about how to use it (12, 17). Thus, providing more training on VHA features than was provided in most of the studies in this mini review may help older adults to more fully realize the potential of the devices to reduce social isolation and loneliness (12, 17, 29, 30).

Methodological Findings

All studies included in this mini review were exploratory or descriptive with small ($\leq$30) sample sizes. Hence, the findings must be interpreted cautiously due to the voluntary, self-selected nature of the studies, and the lack of control groups. Further, only seven studies met the inclusion criteria, most of which were from the authors' libraries. One explanation for the lack of results from the database search is that VHAs have only been on the market for about 7 years so research on this topic is relatively scant. In addition, the devices are referred to by a plethora of other names in the literature, including digital assistants, conversational agents, and smart speakers. Consequently, database indexes do not have a consistent keyword for the devices, which limits the utility of systematic searches. Findings across studies consistently noted that VHA use offered companionship to older adults and may reduce social isolation and loneliness. Nonetheless, the small number and methodological characteristics of the studies reviewed portray that the state of the science of older adults' VHA use and its influence on social isolation and loneliness is in its infancy. Thus, there are many limitations to current knowledge, and the findings from the studies included in this mini review may not have adequately represented some of the risks and ethical controversies relevant to VHA use.

Personal and Ethical Considerations

The findings of this mini review noted potential benefits of VHAs, but there are also potential risks associated with VHAs. Privacy concerns, often noted as a barrier to VHA use (24, 26, 31), did not emerge as a theme in the studies included in this mini review, possibly attributed to self-selection bias. Older adults who had privacy concerns (e.g., VHA is "always listening") probably declined to participate in the studies, whereas those who participated had minimal concerns about privacy. Technological advances and regulatory safeguards are needed to mitigate privacy threats from VHA use (11, 24). The AI incorporated into VHAs is designed to mimic cognitive,

emotional, and social intelligence, which contributes to the personification of VHAs (32) and to users viewing them as companions. Little is known about the eventual behavioral consequences of personifying a device (32), particularly when a person has cognitive impairment. Relatedly, an inability to remember the necessary commands to interact with a VHA may create frustration and agitation in people, particularly those with cognitive deficits (33). Conversely, AI is also being used to automate discourse analysis which may improve communication between people with dementia and their caregivers in the future (34). Concerns also exist about inequality and cultural and population biases built into technology-driven AI (35). For example, one study noted racial disparities in the automated speech recognition of VHAs (36). Alternatively, another study involving adults with intellectual disabilities had improvements in speech intelligibility after VHA interactions (37). Additionally, commercially available VHA devices are relatively affordable, but that benefit involves the risk of corporate-infused biases and targeted, personalized marketing opportunities (32), which may pose vulnerabilities for older adults. Virtual Home Assistant set-up and many functions require a smartphone and home internet access, which involves monthly costs. Taken together, the cost is prohibitive for some older adults (29). Thus, while the findings of the mini-review illustrate the potential benefits of VHAs for reducing social isolation and loneliness, there are also associated ethical considerations inherent to VHA use.

CONCLUSIONS AND FUTURE DIRECTIONS

Loneliness and social isolation are prevalent among older adults and pose serious health risks (5–7, 38). The results of this mini review suggest VHAs may offer a strategy to improve social connectedness and reduce loneliness for some older adults. A consistent finding was that many older adults perceived VHAs to be a companion. However, the state of the science is in its infancy. More research is needed to confirm these findings in larger, rigorously designed studies. Research is needed that quantitatively measures social isolation and loneliness outcomes among older adults using VHAs, as are studies that measure other known correlates to social isolation and loneliness, such as depressive symptoms (39), cognitive status (40), and functional ability (38). Additional research to define evidence-based strategies to teach VHA use skills to older adults is also needed. Ongoing refinements to the natural language processing features of VHAs to enhance the conversational experience will promote ease of use among older adults and improve the social attraction of the devices (17, 21), which may strengthen perceptions of the devices as a companion and reduce social isolation and loneliness. However, research to better understand the risks and benefits of using VHAs and other AI-infused technology is required. Public awareness of the potential risks and benefits is necessary for older adult users and other vulnerable populations to make informed choices (35). Continued research, public involvement in product development, and policy to promote ethical, unbiased AI that protects the privacy of users is necessary (35). In addition, the growth of all types of digital health necessitates devising strategies for affordable and reliable internet access to promote health equity (41, 42).

AUTHOR CONTRIBUTIONS

CC formed the concept of the mini review and identified the included studies in this mini review. CC and PW completed the database search, reviewed the literature, and drafted the mini review. All authors reviewed and edited the mini review.

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BRIEF RESEARCH REPORT
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Demographic and Psychographic Factors of Social Isolation During the COVID-19 Pandemic: The Importance of Technology Confidence

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The COVID-19 pandemic presents an unprecedented situation in which physical distancing and "stay at home" orders have increased the pressures for social isolation. Critically, certain demographic factors have been linked to increased feelings of isolation and loneliness. These at-risk groups for social isolation may be disproportionately affected by the changes and restrictions that have been implemented to prevent viral spread. In our analysis, we sought to evaluate if perceived feelings of social isolation, during the COVID-19 pandemic, was related to demographic and technology-related psychographic characteristics. Older adults across Canada were surveyed about their demographic background, their feelings concerning confidence and proficiency in technology use, and how frequently they have felt isolated during the pandemic. In total 927 responses from Canadians over 65 years old, of varying demographic characteristics were collected. Our data shows that many older adults are feeling isolated "Often" or "Some of the time" in 2020, regardless of most demographic factors that have been previously associated with increased isolation risk. However, feelings of proficiency in using technology was an important factor affecting feelings of isolation. Given that technology proficiency is a modifiable factor, and remained significant after adjustment for demographic factors, future efforts to reduce social isolation should consider training programs for older adults to improve technology confidence, especially in an increasingly digital world.

Keywords: older adults, communication technology, confidence, demographic factors, social isolation, pandemic

INTRODUCTION

Feelings of social isolation and loneliness is a global public health concern that particularly affects older adults (1). It is well-established that many negative health consequences such as declines in cognitive function, mental health, decreased immune function, and mortality are associated with loneliness and social isolation in older adulthood (2–4). Related to this, a number of studies have begun to explore the sociodemographic characteristics that may predispose individuals to these feelings of isolation. Some of the demographic risk factors for loneliness and social isolation among older people include but are not limited to, disability, low income, living alone, poor health, less education, and certain racial or ethnicity differences (5, 6).

The COVID-19 pandemic presents an unprecedented situation in which physical distancing and "stay at home" orders have increased the pressures for social isolation. Many businesses, places of education, and recreational facilities were shuttered to prevent the spread of the virus, but also consequently cut off the potential for in-person social engagement through these outlets. As a result of these orders, we have also seen a large-scale transition to a heavy reliance on technology for social connectedness and everyday services (7, 8). With these changes, the impact on those who are demographically at risk for social isolation may be disproportionately amplified.

In our analysis, we sought to evaluate if perceived feelings of social isolation, during the COVID-19 pandemic, were related to demographic characteristics that have been previously considered to be more likely to experience social isolation. Furthermore, because of the current necessity of technology for social communication and services, we proposed to investigate the relationship between the psychographic characteristics of technology confidence and feelings of social isolation. Understanding the associations of sociodemographic and psychographic factors related to social isolation may aid in directing strategies and resources toward groups who are demonstrating heightened feelings of isolation during this pandemic.

MATERIALS AND METHODS

Participant recruitment and data collection were completed by Environics Research, a commercial company, commissioned by AGE-WELL NCE (www.agewell-nce.ca) in Canada. Data was provided to the authors for secondary analysis and approved by the Research Ethics Board at Simon Fraser University REB #30000195.

Canadian adults over the age of 50 were invited to complete the survey and answer questions on their attitudes and behaviors concerning technology. Sampling and recruitment were completed by the Environics research team. Specific quotas were outlined for each survey to ensure, (1) at least 45% of the responses collected were over the age of 65 years old; (2) 51% of the sample was female, and (3) the distribution of geographical responses aligned with proportional representation of the population. The surveys were offered in both French and English and responses were collected online, or via computer-assisted telephone interview (CATI). For our analysis, only the data of those aged 65 or older was processed.

Various self-reported demographic characteristics were collected to describe the sample: age; gender; living in a rural or urban setting; housing status (living alone or with others); relationship status (in a partnership or not); level of income (Low: $39,999 or less, Middle: $40,000–$99,999, or High: $100,000 or more); level of education (high school equivalent or less, technical degree or some post-secondary, completed university degree); self-identify as a Black, Indigenous or Person of Color (BIPOC); self-identify as a person with a disability.

Two psychographic measures were also collected to describe the sample. Survey participants were asked to rate on a Likert scale their confidence to use technology, as well as how "Tech-savvy" they felt there are. Responses for the technology confidence rating were sorted into "Confident," those who reported some level of confidence, and "Not Confident," those who reported some level of non-confidence. Similarly, those that responded that they felt some level of Tech-savviness were classified as "Tech-savvy" and those that reported negatively on the scale were classified as "Not Tech-savvy."

To collect feelings of isolation, survey respondents were asked, "how often did you feel isolated from others?". Response options were "Hardly ever," "Some of the time," or "Often."

Statistical Analysis

To examine the unadjusted bivariate relationship of demographic and psychographic characteristics on feelings of isolation we conducted chi-square testing ($\alpha = 0.05$). Significant associations were further evaluated using Bonferroni corrected pairwise z-testing, where appropriate, to evaluate where proportions differed. We also performed unadjusted and adjusted multinomial logistic regression to test the overall effects and odds ratios of sociodemographic factors of feelings of isolation "hardly ever" and "some of the time" compared to those that reported social isolation "often."

RESULTS

A total of 2,026 response were collected. For our analysis of responses aged 65 and over the sample included 927 total responses. Demographic and psychographic characteristics of the sample are reported in **Table 1**. Within the entire sample, 15.4% reported feeling isolated "Often," 49.7% "Some of the time," and 34.8% "Hardly ever" in the past few months, during COVID-19.

Bivariate Relationship Effects

The sample was categorized into demographic groupings to compare feelings of isolation between various demographic characteristics (**Table 1**). Level of income was identified as having a significant relationship to feelings of isolation ($X^2 = 11.589$, $df = 4$, $p = 0.021$). Specifically, the proportion of participants who reported feelings of isolation "Often" was significantly less for those who were identified as the highest income earners (6.6%), compared to those who were the middle (15.9%), and low-income earners (18.3%, $p < 0.05$). Furthermore, the proportion

TABLE 1 | Reported feelings of isolation of older adult respondents in the year 2020, organized by demographic characteristics.

		Hardly ever	Some of the time	Often	Chi-square *p*-value
Age group	65–74 ($n = 631$)	34%	51%	15%	n.s
	75+ ($n = 296$)	37%	47%	17%	
Gender	Male ($n = 449$)	38%	48%	15%	n.s
	Female ($n = 478$)	32%	52%	16%	
Location	Rural ($n = 144$)	73%	21%	6%	n.s
	Urban ($n = 783$)	69%	27%	4%	
Housing	Live alone ($n = 332$)	34%	49%	18%	n.s
	Live with others ($n = 572$)	36%	51%	13%	
Relationship status	Not in partnership ($n = 367$)	36%	46%	17%	n.s
	In partnership ($n = 560$)	34%	52%	14%	
Income	Low ($n = 229$)	36%	$46\%_{a}$	$18\%_{c}$	0.021
	Middle ($n = 422$)	34%	$50\%_{a,b}$	$16\%_{c}$	
	High ($n = 137$)	34%	$59\%_{b}$	$7\%_{d}$	
Education	High school or less ($n = 239$)	36%	47%	16%	n.s
	Some post-secondary ($n = 313$)	33%	49%	18%	
	University graduate ($n = 375$)	36%	52%	13%	
BIPOC	No ($n = 872$)	35%	50%	15%	n.s
	Yes ($n = 41$)	32%	51%	17%	
Disability	No ($n = 779$)	35%	50%	$14\%_{a}$	n.s
	Yes ($n = 142$)	31%	47%	$22\%_{b}$	
Technology confidence	Confident ($n = 669$)	36%	50%	$14\%_{a}$	0.039
	Not confident ($n = 172$)	34%	44%	$22\%_{b}$	
Tech-savviness	Tech-savvy ($n = 500$)	$37\%_{a}$	49%	$14\%_{a}$	0.021
	Not Tech-savvy ($n = 327$)	$30\%_{b}$	50%	$20\%_{b}$	

P-values for overall chi-squared relationship testing is reported (n.s, not significant). Each subscript letter indicates a significant difference ($p < 0.05$) in z-proportions testing with the demographic grouping (i.e., non-matching subscripts indicates significant proportional differences). Not all demographic groupings total 927 due to non-responses or preference to not answer.

of those that reported feelings of isolation "Some of the time" was statistically greater in the high-income grouping (59.1%) compared to the low income (45.9%, $p < 0.05$).

Chi-squared testing for self-identified disability status and feelings of isolation returned non-significant overall, however, the proportion of those that reported feeling isolated "often" was greater for those who self-identified as a person living with a disability (21.8%) compared to those without (14.4%, $p < 0.05$).

Within all other demographic groupings, there were no significant relationships or differences in proportions in reported feelings of isolation. All demographic groups reported >60% of the respondents feeling isolated "Some of the time" or "Often" (range 62–68%).

When the 2,020 sample was sorted by participant's psychographic characteristics significant differences were evident. Individuals who reported that they were "not confident" in their use of currently available technologies were those who were reported feeling isolated "Often," 22.1% compared to 14.2% of those who reported being "Confident" in their ability to use current technology ($X^2 = 6.473$, $df = 2$, $p = 0.039$). Similarly, there was a significant relationship between reported feelings of isolation and individual's perception of their "Tech-savviness" ($X^2 = 7.698$, $df = 2$, $p = 0.021$). Specifically, those who reported themselves as being "Not Tech-savvy" had a significantly greater proportion of participants report feeling isolated "Often" (20.2%) compared to 13.8% of those who reported themselves as "Tech-savvy" ($p < 0.05$). Those who reported being "Tech-savvy" also had a significantly greater proportion (37.2%) of those who reported feelings of isolation "Hardly ever," compared to 30.3% of those who reported themselves as "Not Tech-savvy" ($p < 0.05$).

Multinomial Multivariable Regression Effects

Findings for the unadjusted regression models are reported in **Table 2**. After adjustment for sociodemographic variables older adults who reported "hardly ever" feeling isolated were more likely to be those who identified as being a person without disability (OR 1.95, 95% CI 0.99–3.85) and those who reported themselves as tech-savvy (OR 2.04, 95% CI 1.10–3.77) when compared against those that felt isolated "often." After adjustment, there were no significant differences demonstrated for those who reported feeling isolated "some of the time" compared to "often."

TABLE 2 | Adjusted and unadjusted multinomial logistic regression of feelings of isolation "Hardly ever" ($n = 323$) and "Some of the time" ($n = 461$) referenced to "Often" ($n = 143$).

	Hardly ever OR (95% CI)		Some of the time	
	Unadjusted	**Adjusted**	**Unadjusted**	**Adjusted**
Age group				
65–74	1.02 (0.59, 1.76)	1.05 (0.61, 1.81)	1.01 (0.60, 1.71)	1.04 (0.62, 1.74)
75+	1.00	1.00	1.00	1.00
Gender				
Male	1.26 (0.75, 2.13)	1.24 (0.73, 2.08)	0.90 (0.55, 1.48)	0.89 (0.54, 1.46)
Female	1.00	1.00	1.00	1.00
Location				
Rural	1.28 (0.67, 2.45)	1.26 (0.66, 2.41)	1.02 (0.55, 1.93)	1.02 (0.55, 1.91)
Urban	1.00	1.00	1.00	1.00
Housing				
Live alone	0.68 (0.30, 1.51)	0.68 (0.31, 1.50)	0.82 (0.38, 1.77)	0.83 (0.39, 1.76)
Live with others	1.00	1.00	1.00	1.00
Relationship status				
Not in partnership	1.65 (0.72, 3.76)	1.76 (0.78, 3.98)	1.08 (0.49, 2.38)	1.13 (0.52, 2.46)
In partnership	1.00	1.00	1.00	1.00
Income				
Low	0.76 (0.29, 2.00)	0.76 (0.29, 1.99)	0.40 (0.16, 1.03)	0.40 (0.16, 1.01)
Middle	0.54 (0.23, 1.23)	0.54 (0.24, 1.22)	0.45 (0.21, 0.99)*	0.45 (0.21, 0.97)
High	1.00	1.00	1.00	1.00
Education				
High school or less	0.78 (0.40, 1.53)	0.79 (0.40, 1.54)	0.93 (0.50, 1.75)	0.94 (0.50, 1.77)
Some post-secondary	0.89 (0.49, 1.61)	0.86 (0.47, 1.55)	0.92 (0.52, 1.62)	0.90 (0.51, 1.58)
University graduate	1.00	1.00	1.00	1.00
BIPOC				
No	2.36 (0.64, 8.73)	2.24 (0.61, 8.26)	0.91 (0.31, 2.64)	0.89 (0.31, 2.58)
Yes	1.00	1.00	1.00	1.00
Disability				
No	2.05 (1.04, 4.06)*	1.95 (0.99, 3.85)*	1.39 (0.75, 2.57)	1.35 (0.73, 2.50)
Yes	1.00	1.00	1.00	1.00
Technology confidence				
Confident	0.93 (0.46, 1.86)	0.92 (0.46, 1.85)	1.29 (0.67, 2.47)	1.27 (0.67, 2.43)
Not confident	1.00	1.00	1.00	1.00
Tech-savviness				
Tech-savvy	2.07 (1.12, 3.84)*	2.04 (1.10, 3.77)*	1.35 (0.76, 2.38)	1.33 (0.75, 2.36)
Not Tech-savvy	1.00	1.00	1.00	1.00

*$p < 0.05$.

DISCUSSION

Our study aimed to investigate whether feelings of isolation were related to demographics characteristics that have previously been associated with greater risk of social isolation and loneliness. Additionally, we aimed to explore the effects of psychographic characteristics related to technology confidence on feelings of isolation. Our data set shows that many older adults are feeling isolated "Often" or "Some of the time" in 2020, regardless of various demographic factors that have been previously associated with increased isolation risk (6). We expected to see a disparity in reported levels of isolation based on demographic groupings that are associated with risk, with those belonging to at-risk demographic groupings having more reported frequency of feelings of isolation. Instead, we found that a large proportion of older adults are experiencing feelings of isolation at least "some of the time" regardless of almost all demographic factors evaluated.

Of the demographic factors evaluated in the bivariate analysis, income level, and self-reported disability status were the only demographic factors that indicated significantly different proportions of reported feelings of isolation. Where those who were low-income or middle-income earners, or had a disability

reported feeling isolated "often" at a greater proportion than their demographic counterparts. These results align with our expectations and previous studies, where those with lower income and reported disability have been identified as those who are more likely to be socially isolated or report loneliness (6). Unexpectedly, however, our results also indicated that the high-income earners reported feeling isolated "some of the time" at a greater proportion than low-income earners. We speculate that this may be due to COVID-19 restriction and closures. With social and physical restrictions in place, these higher-income individuals may not have the opportunities for the interaction they may have previously expected or experienced. Despite this specific observation, the overall relationship of reported isolation and income level was found to have an inverse relationship, lower income was associated with more frequent feelings of isolation.

Our results for overall reported feelings of isolation are somewhat comparable to previous reports that evaluated feelings of isolation in older adults. Prior to COVID-19, a 2012 published study (9) identified that 18% of older adults reported feelings of isolation some of the time. Similarly, Hawley et al. (10) found that 18% of adults aged 62–91 reported frequent loneliness (with an additional 29% reporting occasional loneliness). Our data indicated that 15% reported feeling isolated "Often" and 50% "Some of the time." While the proportion of individuals in our data set who reported feelings of isolation often is similar to previous studies, it is worth noting that the proportion of those who reported feelings of isolation some of the time is considerably greater than previous studies. This discrepancy may help explain why we did not observe as many significant differences in demographic factors as expected. It is likely, that because of the COVID-19 pandemic, individuals of many different characteristics who would not otherwise have reported feelings of isolation are now doing so (11). Meanwhile, those who were already feeling isolated before the pandemic are being "hidden" by the increased numbers who reported feeling isolated in the context of the pandemic. Essentially COVID-19 appears to have acted as a catalyst in reducing the demographic effect on feelings of isolation. However, we also explored the effects of two psychographic characteristics and found significant differences.

When evaluating the respondents by psychographic factors our results both within our bivariate and multivariate analysis indicated that those who felt more proficient in their abilities to use existing technologies were those who responded that they had less frequent feelings of isolation compared to those who felt less confident or tech-savvy. This finding is critical to consider in the context of COVID-19 and the transition to technology-based services and communication to protect public health and safety. As our results indicate, lower confidence in using current technology is related to feelings of isolation. Hence, supporting older adults to feel confident in using technology may be a significant factor in ameliorating experiences of social isolation during the COVID-19 pandemic. Previous studies have indicated that older adults can benefit from technology by reducing loneliness and increasing social contact (12–14), however, if individuals are not confident in using these technologies these benefits may not be fully realized. Rolandi et al. (15), support this theory through their findings; older adults who were trained in using social media platforms had less frequent feelings of loneliness and a more maintained level of social engagement during the pandemic lockdowns compared to untrained older adults.

Despite this previous evidence, we cannot be sure of the directionality of our observations. Do the older adults in our survey feel less isolated because they are using technology more during the pandemic to remain connected, and thus building a sense of mastery for technology and feeling less isolated, or does feeling less isolated emanate from the confidence that they have the capacity to remain connected through technology? Additionally, those that see themselves as socially isolated may have less access to technology and thus lower technology confidence. Furthermore, additional external factors related to COVID-19 not evaluated in our data could be influencing feelings of social isolation; technology confidence may not be the main driver of heightened frequency of feelings of social isolation.

It should also be mentioned that it is possible there may be unintended consequences to an increased use of technology for older adults. Research by Knowles and Hanson (16) demonstrates that some older adults do not find using technology rewarding in an of itself and consciously avoid "getting caught up in" digital life. Importantly, while some older adults may find features like social media to be useful for keeping in contact with family, many often feel social networking is time-wasting and have an aversion to being glued to one's mobile phone. Having to substitute normal face-to-face interactions with a digital stand in may lead some individuals to have negative association with these interactions and feel further isolated. That being said, in the context of a global pandemic where digital interaction may be the only safely available interaction, investigating how improving feelings of confidence and mastery for technology usage, in tandem with personal preferences, may be worthwhile to investigate in alleviating feelings of loneliness and social isolation.

While the research is based on a sample of Canadian older people, Canada is probably not untypical of many countries across the world. In all developed countries, physical distancing policies, and restrictions on social interaction were implemented, while many essential services were migrated to online platforms. As the COVID-19 pandemic continues to fluctuate, new variants emerge, along with the prospect of future pandemics, the longer-term implications of isolation, support for older adults in their use of technology and how these fit with personal preference and wants, should become a priority of policy and practice.

In conclusion, our results confirm that many older adults are experiencing feelings of isolation and contrary to previous studies, the majority of demographic factors examined within our study do not contribute to significant differences in feelings of isolation. Critically, in the context of a digital world during a pandemic, feelings of proficiency in using technology appears to be an important factor related to feelings of isolation. However, we note that social isolation among older adults may not so easily be cured by access and use of current technology. But, given that technology proficiency is a modifiable factor, and was significant after adjustment for demographic factors, future efforts to reduce social isolation could consider training programs for older adults to improve technology confidence.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by data was provided to the authors for secondary analysis and approved by the Research Ethics Board at Simon Fraser University REB #30000195. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

AS, DS, and AM conceived the study, and were part of overall direction and planning. BH analyzed the data with input from AS. BH wrote the manuscript with input from all authors.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Feasibility and Enjoyment of Exercise Video Games in Older Adults

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Introduction: Several interventions have been developed to enhance social connectedness among older adults. However, little research has demonstrated their performance in a social distancing environment. Exergames are not only beneficial to older adults' physical and cognitive health, but they also allow players to interact with each other at a distance, which can reduce loneliness and increase social connection. The aim of this pilot study was to investigate older adults' perceptions of two commercially available exergames.

Methods: Twenty healthy community-dwelling older adults (M age = 73.30, SD = 5.95, range = 65–84 years, 80% women) were recruited in this pilot study between July 2019 and February 2020. They were asked to play two exergames for 10 min each on the Xbox One with Kinect console: Just Dance and Kinect Sports Rivals. After gameplay, they provided both quantitative and qualitative feedback on these games.

Results: Participants reported an average rating for exergame enjoyment. Greater enjoyment was significantly related with younger age and greater extraversion but not gender. Participants were highly motivated to do well on the games but reported lower scores for likelihood of playing these games in the future. Greater likelihood of future play was associated with younger age but not gender or extraversion. "Not aerobic or strengthen enough; not enough exertion," and "slower movements, repetition, clear purpose of doing the exercise" were some factors that would influence their decision to buy and play these games.

Discussion: The preliminary results of this pilot study suggest that exergames may help address social isolation and loneliness—particularly during times of social distancing. Before applying exergames as a social isolation or loneliness intervention for older adults, study replication in larger representative studies and future work that examines important design issues related to older adults' experiences with these games is needed.

Keywords: aging, social isolation, social connectedness, exergame, feasibility, video games

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INTRODUCTION

Social connectedness, or the "subjective evaluation of the extent to which one has meaningful, close, and constructive relationships with others" [(1) p. 43], is an essential component of well-being for older adults (2, 3). Older adults are at greater risk of feeling socially disconnected compared to younger age groups due to several age-normative isolation-inducing transitions including retirement and the subsequent loss of a social work environment, the death of close friends and family, and limited mobility as a result of age-related physical and cognitive impairments (3–5). The COVID-19 pandemic, and the resulting need for social distancing, is a non-normative transition that placed older adults at great risk for social isolation and loneliness (6–11). There is a need for activities that address social isolation and loneliness among older adults while adhering to social distancing requirements. The current study presents older adults' perceptions of two commercially available exercise video games (exergames) which hold promise for promoting social connectedness among older adults in a virtual environment.

Social connectedness safeguards against one of the most pervasive risks to older adults' health and well-being: loneliness. In fact, some scholars propose that social connectedness can be conceptualized as a lack of loneliness (1). Because loneliness has been linked to reduced life satisfaction, depression, and poor health outcomes (12, 13), enhancing social connectedness has the potential to bolster overall emotional, psychological, and physical well-being (4, 14–16). Characterized by caring/feeling cared for by others and having a sense of belonging (1), feeling socially connected is largely dependent on one's mindset; this provides space for a variety of interventions to target this construct.

For community dwelling older adults, several interventions aimed at increasing in-person connections have been developed to enhance social connectedness. The majority of these interventions have a specific aim of increasing the frequency of social contact (17, 18). In a review of 39 interventions targeting social connectedness/loneliness in older adults, O'Rourke et al. (19) found the two most prevalent intervention types focused on enhancing personal contact and implementing activity and discussion groups. Inconsistent use of measures and evaluative tools make it difficult to assess the efficacy of current interventions (19), though most studies suggest a variety of social supports, especially those that connect individuals around shared activities, can promote social connectedness and overall well-being for older adults (2, 20).

One challenge of the COVID-19 pandemic is how to promote social connectedness and well-being without the use of traditional in-person intervention formats. Exergaming has the potential to increase social connectedness, physical activity, and leisure opportunities among older adults during times of social isolation including the COVID-19 pandemic. Exergames are a type of game, often technology-based, in which participants are required to be physically active to play (21). Although originally designed for entertainment, exergames that combine digital gaming and physical activity are increasingly used for health promotion including physical (22–26), cognitive (23, 24, 27), and emotional well-being (26, 28). Exergaming is a social activity that provides opportunities for players to interact with each other, which may foster connectedness and reduce loneliness. Such social benefits of exergame play are drawing increasing interest from the research community (29–31), and exergames show promise for enhancing social well-being among older adults (32). Not only do exergames show promise in reducing loneliness, increasing social connection, and fostering positive attitudes toward others (26, 32, 33), but exergames may provide opportunities for social engagement with peers and family members (34). Intergenerational play may be particularly beneficial for older adults, as gaming with a younger partner significantly reduced older adult loneliness compared to passive television viewing with a younger partner (28). The positive social benefits may even extend to observers, as older adult spectators reported enjoying "cheering on" their gaming peers (34).

Exergames are a viable tool to address social isolation and loneliness among older adults, but more research on the exergaming experience is warranted. Before exergames can be prescribed as a way to combat social isolation and loneliness, especially in times when social distancing is required, it is imperative to first establish older adults' thoughts and experiences regarding these games. Specifically, research is needed to understand whether older adults like exergames, which components of exergames they like and dislike, and if there are subgroups of older adults who are more likely to enjoy exergames. If older adults enjoy the exergames they are playing, they are likely to engage more with the games and receive any potential social engagement benefits. If older adults do not enjoy the exergames or certain aspects of the games, they are likely to not play and will not receive such benefits. The current pilot study will examine older adults' perceptions of two commercially available exergames using qualitative and quantitative approaches. First, the current study will describe older adults' preferences for and attitudes toward exergames. Specifically, it will assess whether older adults prefer one game over another, which elements of gameplay they like/dislike, and whether they believe playing with a partner would make exergame play more enjoyable. Second, the study will explore variations in preferences for and attitudes toward exergames by age, gender, personality, and prior technology experience.

MATERIALS AND METHODS

The Feasibility and Enjoyment of Exergames (FLEX) study is a pilot study of 20 healthy community-dwelling older adults conducted between July 2019 and February 2020. The purpose of the FLEX study was to explore the feasibility of an exergame system for use by community-dwelling older adults in a future larger intervention trial. Participants were recruited in a small town in Pennsylvania from flyers in local community spaces (e.g., coffee shops, senior centers) and from a recruitment database of older adults residing in the local community who were interested in being contacted for research studies. Eligible participants completed a take-home packet prior to a 75-min lab visit. Participants between the ages of 65 and 85 who were willing and able to do moderate to vigorous physical activity

were included in the study. Exclusion criteria included: residing in a nursing home or other institution; being older than 85 or younger than 65 years of age; having no English language proficiency; having participated in an organized exercise program for more than 2 h/week in the past 2 years; using a video game console for more than 2 h/week in the past 2 years; using a walker, cane, and/or wheelchair; having more than two falls in the past 2 months; reporting Parkinson's disease or other motor diseases, uncontrolled asthma, COPD, peripheral neuropathy, diabetes, cardiac disease, or hypertension; having a history of traumatic brain injury; being advised by a medical professional to not do moderate to vigorous physical activity; and having a Memory Impairment Screen-Telephone score of 4 or lower (35). This study was approved by the Pennsylvania State University Institutional Review Board and has been preregistered on Open Science Framework[1], where detailed study information can be found.

Exergames

This study utilized two commercially available exercise video games, Just Dance and Kinect Sports Rivals, on the Xbox One with Kinect console. Exergames were played on a sixty-inch 1,080 p LED television. Both exergames are controlled by participant movement by the Kinect console's motion-sensing camera. Just Dance is a dance-based exergame where participants mimic the dance movements of the on-screen character. Participants danced to three songs for 3 min each. Game points are rewarded based on their dance movement accuracy. Kinect Sports Rivals is a sports-based exergame where participants competed in three sporting events for 3 min each: bowling, tennis, and target shooting. The exergames were set up prior to the lab visit so participants did not have to navigate any screens. Participants played each exergame for 10 min, with a 5-min break offered in between gameplay. Game presentation was counterbalanced such that half participants ($n = 10$) played Just Dance first and half played Kinect Sports Rivals first. The research assistant observed gameplay and offered instructions as needed.

Measures

Personality

Personality was assessed during the in-person visit before exergame play using the Big Five Inventory 44-Item (36). The Big Five Inventory is a self-report questionnaire that assesses five personality traits (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism). The current study included Extraversion and Openness to Experience as predictors of exergame experience.

Mobile Device Proficiency

As part of the screening process, participants did not have prior experience with console video games. To assess prior technology experience, a measure of mobile device proficiency was included in the current study in the take-home questionnaire. The Mobile Device Proficiency Questionnaire (MDPQ) is an eight-item questionnaire which assesses proficiency in four areas of mobile device usage: Mobile Device Basics, Communication, Data and File Storage, Internet, Calendar, Entertainment, Privacy, and Troubleshooting, and Software Management (37). Proficiency scores ranged from 1 to 5 with the lowest rating having "never tried" the listed action on a mobile device and the highest rating indicating they can "very easily" carry out the action on a mobile device (i.e., "Using a mobile device I can setup a password to lock/unlock the device"). The total MDPQ score is the sum of the averages of the four subscales, with possible scores ranging from 0 to 20.

Experiences With Exergame

Participants' experiences with the exergames were measured quantitatively and qualitatively. Participants provided quantitative feedback by responding to the following items on a scale of 1 to 5, where higher score represent more favorable opinions: (1) enjoyment of the exergames ("Did you enjoy the exergame?"), where 1 = disliked and 5 = greatly enjoyed; (2) motivation during game play ("How motivated were you to do well on the exergame?") where 1 = no motivation and 5 = highly motivated; and (3) likelihood of playing the exergame in the future ("How likely are you to play an exergame like the one you just played in the future?") where 1 = highly unlikely and 5 = highly likely. Participants also reported how likely they were on a scale from 0 (very unlikely) to 3 (very likely) to say, "I feel like I have the money to play a game like this in my home." Participants provided qualitative feedback by writing their responses to the following items: "What was the most enjoyable part of the exergame?," "What was the least enjoyable part of the exergame?," and "Would playing with a partner make exergaming more enjoyable?." For the last item, all participants wrote some version of "yes," "no," or "maybe," so this item was converted into a quantitative item where a score of 1 indicates yes/maybe and a score of 0 indicates no.

Current Physical Activity

To characterize participants' current levels of physical activity, we used the Rapid Assessment of Physical Activity (RAPA) assessed at the baseline visit (38). The RAPA is a nine-item questionnaire that measures one's usual aerobic and strength/resistance physical activity engagement. Higher scores indicate a greater level of physical activity engagement.

Mild Cognitive Impairment

The Montreal Cognitive Assessment (MoCA) was administered during the study visit to assess potential mild cognitive impairment (MCI) or dementia (39). The MoCA is a rapid cognitive screening test designed for MCI or dementia detection. It specifically assesses attention and concentration, executive functions, memory, language, visuoconstructional skills, conceptual thinking, calculations, and orientation. Higher scores are thought to reflect normal cognitive function.

Analytic Plan

To accomplish Aim 1 (describe older adults' preferences for and attitudes toward exergames), means and standard

[1]https://osf.io/y8as7/registrations

deviations were calculated for each quantitative measure of exergame experience. Qualitative feedback on exergames is presented in-text to identify elements of gameplay that older adults liked and disliked. To accomplish Aim 2 (explore variations in preferences for and attitudes toward exergames), scores on quantitative measures of exergame experience were compared by gender, age, technology experience, extraversion, and openness to experience. To assess gender differences in continuous outcomes, *t*-tests were conducted. To assess the association between continuous outcomes and age, technology experience, extraversion, and openness to experience, Pearson correlations were conducted. To assess differences in whether playing with a partner would make exergaming more enjoyable by age, technology experience, extraversion, and openness to experience, point-biserial correlations were conducted. Chi square analysis was used to assess gender differences in this item. Significance values were set at $p < 0.05$ and all analyses were conducted in SPSS 26.

TABLE 1 | Demographics of study sample ($N = 20$).

	M (*SD*) or %	Range
Age	73.30 (5.95)	65–84
MoCA	26.05 (2.62)	20–30
Gender (Women)	80%	
Race (White)	95%	
College degree or higher	85%	
Smartphone owner	85%	
Physically active (aerobic)	65%	
Physically active (strength and flexibility)	45%	

RESULTS

Participants

Thirty-eight participants were screened, and 20 met inclusion criteria and were enrolled in the study. **Table 1** highlights demographic information for the study sample. Most participants were female (80%), White (95%), had a college degree (85%), and were smartphone users (85%). The average age of the sample was 73.03 years old (5.95) and the average MoCA score was 26.05 (2.62). Most participants reported participating in aerobic physical activity (65%), and 45% reported being physically active in regards to strength and flexibility as assessed by the RAPA.

Quantitative Feedback

Means and standard deviations for quantitative items are presented in **Figure 1**. Participants reported an average of 3.45 out of 5 ($SD = 1.36$) for exergame enjoyment, though responses ranged from disliked (1) to greatly enjoyed (5). They were highly motivated to do well on the games ($M = 4.0$, $SD = 1.34$) but reported an average of 2.45 out of 5 for likelihood of playing these games in the future. Eight participants responded with a score of 1 indicating that they were "highly unlikely" to play exergames like the ones they just played in the future. Participants were also asked if the cost of an Xbox and the games would impact their likelihood of buying the games; equal numbers of participants said yes (45%) and no (45%) and two participants said "probably." Most participants (80%) were somewhat likely or very likely to say that they have the money to play similar exergames in their home. The majority of participants (65%) said that they would not be likely to buy this game for themselves. Thirteen out of 20 participants said that playing with a partner would make exergaming more enjoyable.

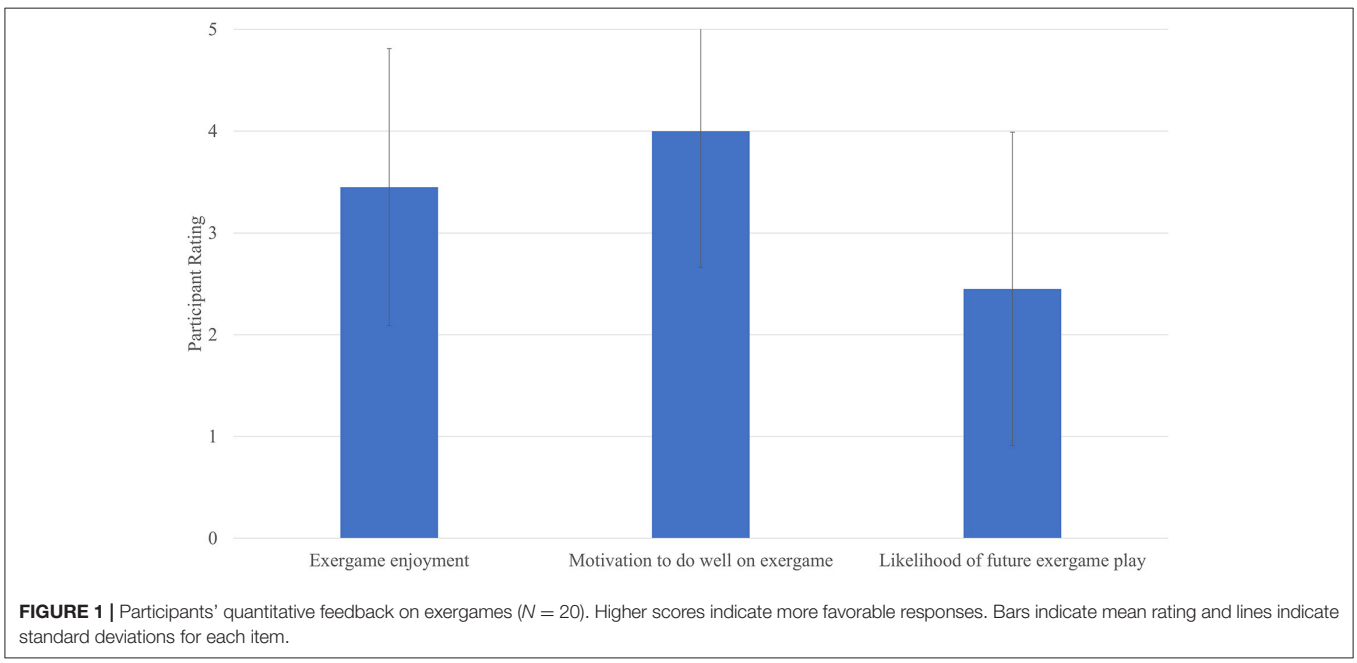

FIGURE 1 | Participants' quantitative feedback on exergames ($N = 20$). Higher scores indicate more favorable responses. Bars indicate mean rating and lines indicate standard deviations for each item.

TABLE 2 | Correlations between demographic variables and exergame experience.

	Enjoyment	Motivation	Future play	Partner play[a]
Age	−0.53*	−0.68*	−0.55*	0.34
Technology experience	0.36	0.37	0.34	−0.54*
Extraversion	0.56*	0.39	0.35	−0.22
Openness to experience	0.28	−0.03	−0.27	−0.22

[a] *Point-biserial correlations. Levene's Test p's > 0.05.*
* $p < 0.05$.

Next, the current study examined whether participant characteristics were associated with enjoyment, motivation, likelihood of future play, and whether playing with a partner would make exergaming more enjoyable. There were no significant gender differences in enjoyment [$t_{(18)} = 0.49$], motivation [$t_{(18)} = 0.41$], likelihood of future play [$t_{(18)} = 0.43$], or indicating that playing with a partner would make the games more enjoyable, $\chi^2_{(1,N=20)} = 2.69$, p's > 0.05. Correlation results are presented in **Table 2**. Correlations between exergame experience and age were large: Older adults reported significantly lower enjoyment ($r = -0.53$), motivation ($r = -0.68$), and likelihood of future play ($r = -0.55$). There was also a large correlation between greater prior technology experience and saying that playing with a partner would not make the exergame more enjoyable (40). However, prior technology experience was not significantly correlated with enjoyment, motivation, or future play. Out of the two personality measures, only extraversion was associated with a measure of exergame experience; older adults scoring higher on extraversion reported greater enjoyment of the exergames ($r = 0.56$). Openness to experience was not significantly associated with any measure of exergame experience.

Qualitative Feedback

Participants were asked to report the most enjoyable and least enjoyable parts of the exergame experience. Seven participants said Kinect Sports Rivals was the most enjoyable, while five said it was the least enjoyable. Five participants indicated that Just Dance was the most enjoyable part, while six said it was the least enjoyable part. Participants also wrote responses not specific to either game, such as saying the most enjoyable part was "winning" and that the games were "fun to play." Responses for "least enjoyable" included "not being very good at them," "standing in one spot," and "all parts." One participant wrote, "I was totally turned off by the graphics, noise, musical distractions in the three games."

Finally, we asked participants to provide any additional thoughts they had on the exergames and what factors may influence these thoughts. A little over half of the participants had no comments to add. Responses to this item include, "Not aerobic or strengthen enough; not enough exertion" though one person wanted "slower movements, repetition, clearer purpose of doing the games." One participant wrote "Not inclined to have yet one more electronic gadget in my house that I would probably lose interest in." Another participant wrote "If the video graphics and music were geared more to Boomers it would be a possibility." This person did not like the graphics and sound in the game, indicating that it was "too much." Three participants requested to stop exergame play prior to the 10-min play period; all three participants stopped play during Just Dance.

DISCUSSION

This pilot study explored older adults' perceptions of two commercially available exergames. Overall, participants' enjoyment of the games was mostly neutral despite being motivated to perform well, and they generally reported they were unlikely to play these games in the future. Participants were about equally split on some opinions about the exergames. For example, some participants said Kinect Sports Rivals was the most enjoyable, while other participants said Just Dance was the most enjoyable. Some participants thought the games were not difficult enough, while others thought the games should be slower. The current study also found that participants' characteristics were associated with their experiences. Older age was moderately associated with lower ratings for enjoyment, motivation, and likelihood of future play. Extraversion was strongly associated with greater enjoyment, and prior technology experience was associated with not saying that playing with a partner would make the games more enjoyable. Gender was not associated with any measure of exergame experience. The results of this small pilot study suggest that exergames may be a possible tool that can be used in older adult populations. If so, such games may help address social isolation and loneliness among older adults particularly during times of social distancing and indicate possible avenues for future research on this important issue.

The current study's findings are similar to other studies of older adults' perceptions of commercially available video games (41, 42). The current study found similar neutral amounts of enjoyment and mixed feedback regarding game difficulty for these commercially available games. The Xbox with Kinect games played in this study were not specifically designed for older adults and this was likely reflected in their feedback. In other studies using exergames specifically developed for older adults, older adults had higher ratings for overall enjoyment and motivation to do well (43, 44). While commercially available games are a cost-effective and quick way to administer interventions, games not designed specifically for older adults may not be as well-received as games designed with older adults in mind.

An important finding in the current study was that game preferences varied. Some participants thought the games were too difficult, while others thought the games were too easy. Because of the nature of this pilot study, findings regarding age, gender, and personality differences in game experience cannot be generalized to the larger population. However, the results have important implications for future research on exergames in this population. Larger, more representative studies should evaluate whether personal characteristics such as age, gender, and personality play a role in people's experiences with exergames.

Exergames could also be effective for groups of older adults who are particularly at-risk for social isolation and loneliness based on characteristics not assessed in the current study. For example, older adults who live alone, do not regularly engage with groups in their community, have physical health issues, and lack connection with close friends or family members are at the highest risk of not being socially connected (45).

Importantly, the findings of the current study suggest that older adults may be receptive to playing exergames with a partner. Over half of the sample indicated that playing with a partner would make exergames more enjoyable. Prior work has found that older adults in nursing home and assisted living settings enjoy the multiplayer components of commercially-available exergames (26, 34, 46). One promising avenue to increasing social connectedness without requiring physical proximity is the use of online multiplayer features of exergames. The exergames played in the current study allow players to interact with other people online. When older adults cannot gather in-person to play games, online multiplayer play would allow them to play games with friends while remaining socially distanced. This option may also benefit areas with limited activity or transportation access such as rural communities. Future work should examine whether the social benefits of multiplayer exergames extend to online formats.

Despite its potential health and psychological benefits to older adults, there are concerns about exergame use in this population. The American College of Sports Medicine encourages older adults to engage in physical activity that incorporates flexibility and balance with slow movements (47). Such activities occur in exergames like Wii Bowling, where users can dictate the speed of movement without negatively impacting their performance. Other activities such as Just Dance, however, require the user to maintain a particular pace in order to perform well on the activity. Games de-emphasizing speed, or those which increase speed demands slowly, may be more appropriate, especially as users become familiar with the gaming system. A related concern of exergames is their use among those with physical limitations. Older adults with physical limitations frequently report social isolation (48), and early evidence suggests exergames may promote social health among those with physical disabilities (26). Despite promising benefits, exergame safety among this population should be considered. Adverse health events due to an exergaming intervention are infrequent, but injury is possible (49). Furthermore, exergames do not always accurately track and register user movement, which can make gameplay frustrating. If the game incorporates a speed element, this may exacerbate a physically-limited user's frustration and decrease self-efficacy, motivation, and enjoyment of the gaming system. As exergames are not intentionally designed for older adult gameplay, it is important to understand adverse events and gameplay experiences among this group, as health care providers and exergame developers should take these into consideration when developing and implementing exergame programs.

This study provides important quantitative and qualitative data about older adults' initial experiences with and perceptions of selected commercially available games. However, there are some limitations worth noting. First, the FLEX study is a small pilot study designed to inform larger future observational and intervention studies. The sample was also relatively homogenous, and most participants identified as white and as women. The percent of white participants was similar to that of the county where participants were recruited (87% white), though the study sample was over-represented by women (80% in study sample vs. 54% of people 65 and older in the population) (50). The lack of gender and racial diversity in the sample limits the ability of study findings to be generalizable to the older adult population at large. Additionally, we could not examine differences in exergame preferences and experiences by educational attainment because all but three participants completed a college degree or higher, compared to 45% of the county's population of adults.

There were also only two exergames examined in the study, while there are many commercially available exergames that may have benefits. This pilot study also was limited in the time participants could learn and play the exergames; it is possible that participants' experiences with the exergames would shift over more gameplay sessions. Finally, the current study was not a training study so social isolation and loneliness were not assessed before and after exergame play. Therefore, no conclusions can be made about the efficacy of such games for reducing social isolation and loneliness. Future research should examine a wider selection of games in diverse and larger samples. Relatedly, more precise examination of specific elements that improve game satisfaction for diverse older adult samples are needed. Future research should examine the development of games that are attractive to a range of older adults and also include evidence-based components to maintain health, social engagement, and well-being. Though the exergames were already set up prior to participants' lab visit, there was limited time during the lab visit to provide instructions and allow participants to practice exergames. This may have contributed to some participants' negative experiences with the exergames reported in quantitative and qualitative feedback.

Exergames have the potential to improve health and decrease social isolation and loneliness in older adults. Games that can be played online may allow for social distancing while providing social connections. The current study lays the foundation for future, larger scale studies on older adults' perceptions of exergames, including comparing commercially available exergames to games designed specifically for older adults, offering different levels of gameplay difficulty, and exploring how exergame play by older adults can be supported remotely. Beyond the COVID 19 pandemic, some older adults may continue to be physically isolated from others for a number of reasons, such as difficulties with transportation. Exergames have the potential to address social isolation and loneliness by providing the opportunity for leisure and physical activity while being socially connected to others if designed in a way that promotes engagement.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Penn State University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SF, BS, and LR contributed to the study design and execution. SF and CD carried out all primary data collection. SF, BS, LR, CP, CD, JT, and AS contributed to writing the manuscript and provided critical feedback. All authors reviewed the results and approved the final version of the manuscript.

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COMMUNITY CASE STUDY
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A Technology Training Program to Alleviate Social Isolation and Loneliness Among Homebound Older Adults: A Community Case Study

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Despite substantial evidence of the negative health consequences of social isolation and loneliness and the outsized impact on older adults, evidence on which interventions are most effective in alleviating social isolation and loneliness is inconclusive. Further complicating the translation of evidence into practice is the lack of studies assessing implementation and scalability considerations for socialization programs delivered by community-based organizations (CBOs). Our primary objective was to describe the implementation barriers, facilitators, and lessons learned from an information and communication technology (ICT) training program aimed at reducing social isolation and loneliness for homebound older adults in a home-delivered meals program. Participants received in-home, one-on-one ICT training lessons delivered by volunteers over a 14-week period with the goal of increasing social technology use. To assess implementation facilitators and barriers, 23 interviews were conducted with program staff ($n = 2$), volunteers ($n = 3$), and participants ($n = 18$). Transcripts were analyzed using thematic analysis. Aspects that facilitated implementation included the organization's existing relationship with clientele, an established infrastructure to deliver community-based interventions, alignment of intervention goals with broader organizational aims, and funding to support dedicated program staff. Challenges to implementation included significant program staff time and resources, coordinating data sharing efforts across multiple project partners, participant and volunteer recruitment, and interruptions due to COVID-19. Implications of these facilitators and barriers for scalability of community-based ICT training interventions for older adults are described. Lessons learned include identifying successful participant and volunteer recruitment strategies based on organizational capacity and existing recruitment avenues; using a targeted approach to identify potential participants; incorporating flexibility into intervention design when working with the homebound older adult population; and monitoring the participant-volunteer relationship through volunteer-completed reports to mitigate issues. Findings from this formative evaluation provide insight on strategies CBOs can employ to overcome challenges associated with implementing technology training programs to

reduce social isolation and loneliness for older adults, and thus improve overall well-being for homebound older adults. Recommendations can be integrated into program design to facilitate implementation of ICT programs in the community setting.

Keywords: information and communication (ICT), community-based organizations (CBOs), older adults, social isolation, loneliness

INTRODUCTION

Social isolation and loneliness are significant threats to physical and mental health, particularly among older adults. Both are associated with poor health outcomes including comorbid conditions (1), cognitive decline (2, 3), and mortality (4). Homebound older adults, comprising 8.3% of community-dwelling older adults in the United States (5), are especially at risk of social isolation and loneliness due to mobility limitations caused by chronic illness, cognitive decline, or injury (6, 7). In fact, being homebound and socially isolated have a synergistic effect on increasing risk of mortality (8).

Meals on Wheels America (MOWA), the leadership organization that supports the national network of Meals on Wheels (MOW) programs, aims to alleviate social isolation and loneliness among homebound MOW clients. Studies suggest that receiving home-delivered meals through MOW can reduce loneliness and improve psychological well-being among homebound older adults due to the social interaction that accompanies meal delivery (9–11). However, some homebound clients need more social connection than provided at the point of delivery, prompting MOWA to expand programming to focus specifically on social connection. Formal efforts currently delivered through MOW programs to address isolation and loneliness lack strong evaluation and have not been scaled widely (12). To bridge this gap, researchers worked with MOWA and a MOW program in Rhode Island to pilot an intervention aimed at alleviating social isolation and loneliness through technology. The program, called Talking Tech, addresses barriers to technology adoption in homebound older adults by providing in-home, one-on-one training to promote digital literacy, virtual connection with family and friends, and participation in a virtual senior center.

Background

In response to physical distancing orders enacted to mitigate the spread of coronavirus 2019 (COVID-19), organizations and researchers alike seek to develop and deliver solutions to combat social isolation and loneliness among older adults, who are at outsized risk of complications caused by COVID-19 (13, 14).

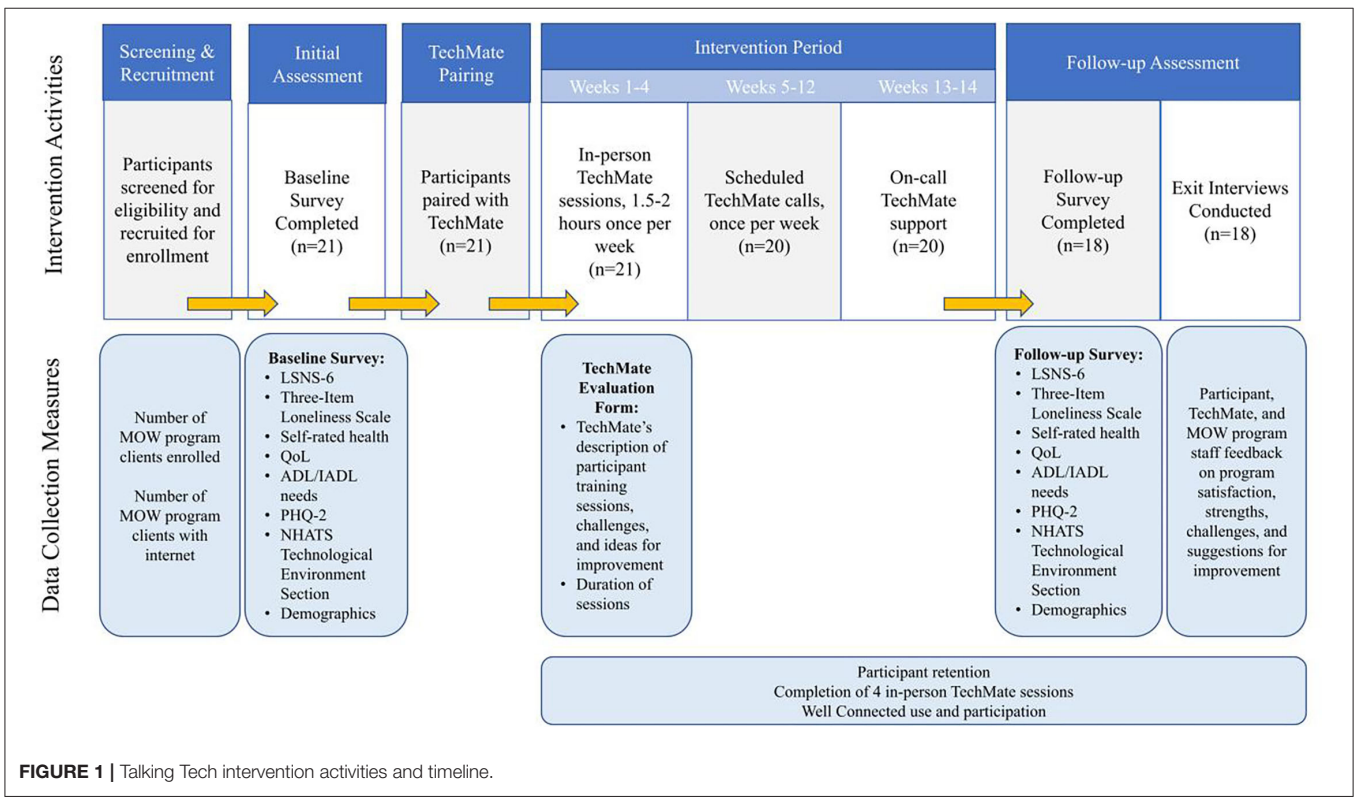

FIGURE 1 | Talking Tech intervention activities and timeline.

TABLE 1 | Intervention partner roles and responsibilities.

Partner organization	Primary role/responsibilities
Meals on Wheels America	Funded and managed Talking Tech implementation, provided ongoing support for MOWRI including training
Meals on Wheels Rhode Island	Coordinated Talking Tech implementation and delivery, including recruiting volunteers and participants, hosting TechMate training sessions, and providing support to participants
Tech4Life	Developed TechMate training session material and module lesson plans, conducted TechMate training
Covia	Operated Well Connected phone and computer sessions; monitored and shared Talking Tech participation in Well Connected sessions
Brown University School of Public Health	Provided evaluation and research support, including designing and conducting baseline and follow-up survey questionnaire and exit interview protocols, and analyzing data

Even before the pandemic, researchers, policymakers, healthcare professionals, and social service providers noted social isolation and loneliness as priorities to address for older adult health (15, 16), yet limited evidence-based options exist for socially isolated or lonely homebound older adults (17–19).

Information and communication technology (ICT) interventions are one potential solution for addressing social isolation and loneliness among older adults (20, 21) by helping them connect to a larger community, gain social support, engage in activities of interest, and boost self-confidence (18, 20). Individualized ICT training has been shown to increase older adults' technology adoption and acceptance (22). ICT interventions can aid homebound, isolated older adults in socialization by allowing them to engage with others from within their home (18, 19). However, barriers, such as lack of technology knowledge, support, broadband availability, and cost, limit the adoption of ICT among older adults (23, 24). These challenges are exacerbated among homebound persons, many of whom are low-income and lack access to technology training and support (25). If tailored to meet the needs of homebound older adults, ICT interventions could fill the gap in needed social isolation and loneliness programs for this population.

The COVID-19 pandemic underscores the need for community-academic partnerships to translate evidence on social isolation and loneliness interventions into practice among frontline service providers, as well as cross-sector collaborations to leverage existing resources and infrastructure to enable continued delivery of services to older adults (13, 26). In the social isolation and loneliness intervention literature, both assessment of community-oriented implementation processes and scalability and sustainability considerations for community-based organizations (CBOs) are not adequately addressed, limiting the ability of CBOs to apply findings to their own work. To encourage adoption of research-informed socialization programming for homebound older adults by CBOs, this community case study describes organization-level facilitators, barriers, and lessons learned from an ICT training program developed *via* a community-academic partnership.

CONTEXT

Talking Tech is a 14-week in-home, one-on-one, volunteer-delivered ICT training intervention. Older adults were paired with a volunteer, called a TechMate, and provided a Surface Pro tablet and internet connection, if needed, to learn how to use a computer device and the internet to socially connect with new and existing contacts *via* 1.5–2 h prepared modules. Talking Tech introduced participants to Well Connected, a national phone and internet-based virtual community that offers over 70 weekly activities, classes, and support and conversation groups. Program activities and timeline are described in **Figure 1**. With support from MOWA, Talking Tech was implemented at Meals on Wheels Rhode Island (MOWRI) from October 2019 to May 2020. Talking Tech is a collaboration between multiple organizations, including: Tech4Life, a technology training company; Covia, which operates Well Connected; MOWA; MOWRI; and a research university (**Table 1**). The study team's university IRB evaluated the study and determined it not to be human subjects research.

Talking Tech was designed by MOWA and the university team, which met weekly to determine program milestones and deliverables. Feedback was sought from MOWRI leadership. During implementation, all partner organizations met weekly to discuss successes and challenges and further refine program delivery. For example, partners discussed improvements to TechMate training in light of TechMate questions and challenges, including additional training on hotspot set up and device troubleshooting and parameters around escalating participant concerns.

ESSENTIAL ELEMENTS OF THE INTERVENTION

MOWRI recruited Talking Tech participants from their home-delivered meal program, using multiple methods including meal delivery driver referrals, program fliers accompanying delivered meals, and email outreach to clients who self-identified as lonely in an annual client survey. Participants were 60 years or older and homebound. Twenty-one MOWRI clients enrolled in Talking Tech. Volunteers were initially recruited from the existing pool of MOWRI's ∼700 annual volunteers through a volunteer appreciation event, by email, and by social media. Due to challenges recruiting existing MOWRI volunteers described below, MOWRI then solicited volunteers through an online volunteer portal, corporate partnerships, and posting fliers at a local university. TechMates were required to have existing computer and internet knowledge. Eighteen individuals volunteered as TechMates.

Tech4Life trained volunteers in a 1-h training session. Volunteers were given a manual containing program goals, expectations for TechMates and participants, module lesson plans with step-by-step instructions and objectives, participant worksheets, and a Well Connected catalog with class schedules. Instructional handouts on setting up the tablet and appropriate shortcuts, setting up a hotspot internet connection, and accessing Well Connected were also included. Training was offered in-person on two occasions in September and November 2019 and by video recording. Thirteen volunteers attended the in-person training and 7 volunteers viewed the recorded training; upon completing training, two individuals withdrew from participating as TechMates due to self-described limited technology comfort and knowledge.

To understand participant experiences and satisfaction with Talking Tech, researchers conducted semi-structured interviews with 18 of the 21 participants after intervention completion; one participant withdrew and two participants were unable to be reached. Interview questions focused on technology usability, perceived impact of internet and Well Connected use on well-being, and satisfaction with Talking Tech components. Three TechMates and two MOWRI program staff were interviewed to understand implementation experiences, facilitators and barriers to program implementation and delivery, observed participant satisfaction, and suggestions for improvement. Initially, participant interviews were conducted within 2 weeks of intervention completion in participants' homes with written informed consent; however, due to COVID-19, only four interviews were conducted in-person. Remaining interviews were conducted by telephone and verbal consent was obtained. Participant interviews lasted between 20 and 90 min. Interviews with staff and TechMates were conducted by telephone after the intervention period and verbal informed consent was obtained. TechMate interviews lasted 40–60 min and staff interviews were 15–60 min. All interviews were audio recorded with consent and transcribed.

During the first 4 weeks, TechMates submitted a report to the Talking Tech coordinator at MOWRI after each participant interaction, documenting the duration of the interaction, participants' questions, participant comfort level and interest with the technology, including the tablet, internet, and Well Connected, challenges, and ideas for program improvement (**Supplementary File 1**). While outside of the scope of this paper, which presents findings on facilitators, barriers, and lessons learned from intervention implementation, additional quantitative data were collected to evaluate outcomes of the intervention. A resulting manuscript is in progress.

Analysis

Qualitative data were analyzed using a thematic analysis approach (27). Three researchers coded the first three participant interviews independently and met to develop a preliminary coding scheme. The coding scheme was then revised after four researchers independently analyzed and discussed all 23 interviews. Transcripts were double coded in rotating pairs to ensure consistency. TechMate reports were reviewed by one researcher for content relevant to lessons learned regarding program implementation. We recorded coding definitions, decisions, and ideas about emerging themes in an audit trail to ensure analytic rigor (28). Qualitative data from interviews and TechMate reports were analyzed using NVivo Version 12 Plus[1].

RESULTS

In this paper, we describe facilitators, barriers, and lessons learned of Talking Tech implementation from the MOWRI perspective, as identified from interviews with Talking Tech participants, volunteers, and MOWRI program staff (**Table 2**).

Implementation Facilitators

Aspects that facilitated Talking Tech implementation included the existing relationship between MOWRI and its clientele; an established infrastructure to deliver community-based programs; alignment of intervention goals with broader organizational aims; and funding to support dedicated program staff and materials.

Both participants and organization staff noted the importance of participants' existing relationship with the delivery organization. For MOWRI, it enabled identification of potentially socially isolated homebound older adults, allowing for a targeted approach to participant recruitment. As existing clients, intervention participants had already developed a relationship with MOWRI personnel. In some instances, participants' regular meal delivery drivers also served as their TechMate. One participant, speaking to the relationship they had developed with their TechMate who also volunteered as their meal delivery driver stated, *"[TECHMATE NAME] delivers my meals so I had met him and knew him but he's just, it was nice having him here… I was very comfortable"* (Participant 1). The existing relationship with MOWRI facilitated trust among participants and familiarity with whom to call if questions or issues arose. One participant described turning to the Talking Tech coordinator at MOWRI when they encountered technology issues since they already knew and were comfortable calling the organization phone number: *"I tried to use [the tablet] quite a few times, and then I got stuck. I don't know what I did, but I called [Program Coordinator]... and she was able to get me out"* (Participant 8).

The home-based, volunteer-delivered model used to deliver Talking Tech was similar to the design of the home-delivered meal program in which volunteers deliver meals to clients homes, which allowed MOWRI to utilize existing volunteer recruitment and training workflows in the operation of Talking Tech. Speaking to the suitability of Talking Tech with existing workflows, one MOWRI staff member noted, *"I definitely think it's something that could be implemented here, for sure. It's a good fit"* (MOWRI Staff 2). Additionally, MOWRI leadership stated that Talking Tech's aims to reduce social isolation and loneliness fit "*perfectly*" within their organization's mission, as well as their push to modernize services (MOWRI Staff 1). These factors led to leadership supporting the program, which facilitated prioritization of meeting program goals among staff.

[1]https://www.qsrinternational.com/nvivo/home

TABLE 2 | Themes of Talking Tech implementation facilitators, barriers, and lessons learned.

Theme/Subtheme
Facilitators
An existing relationship with and history of serving the target population allowed for identification of clients at-risk of being socially isolated or lonely and facilitated trust among participants.
Alignment of ICT program aims with organizational mission and existing infrastructure garnered support from organization leadership.
Funding supported a dedicated part-time staff member to coordinate program implementation and allowed for purchase of program materials.
Subtheme: A part-time program coordinator was critical to successful ICT program implementation and operation.
Barriers
Program staff time and organizational resources needed to implement the program were greater than anticipated.
Data sharing among project partners was inhibited by system and/or organization privacy requirements and sharing restrictions.
Volunteer and participant recruitment were the most challenging component of program implementation.
Subtheme: Potential volunteers and clients were hesitant to join Talking Tech due to the time commitment.
Physical distancing orders from the COVID-19 pandemic led to interruptions in in-person TechMate sessions.
Subtheme: Most participants preferred to delay lessons and resume in-person sessions once safe to do so rather than transition to telephone sessions.
Lessons learned
Identify successful participant and volunteer recruitment strategies based on organizational capacity and existing recruitment avenues.
Use a targeted approach to identify potential participants who are socially isolated or lonely.
Subtheme: Participants and volunteers who were most successful with completing the ICT program had some prior technology experience, suggesting the need for screening questions on technology experience during recruitment.
Provide program flexibility when working with the homebound older adult population.
Subtheme: ICT training programs may not be suitable for all older adults, depending on interest and pre-existing technology knowledge.
Subtheme: Volunteers, participants, and MOWRI staff expressed the need for on-call expertise to assist with troubleshooting complex technology issues.
Subtheme: Adequate volunteer training on working with older adults and technology is necessary.
Implement a process for ongoing, remote monitoring of the participant-volunteer relationship, such as weekly reports, in order to intervene and resolve participant-volunteer issues, when appropriate.

Funding to support the intervention was noted as a critical resource, as it allowed for dedicated staff time and the purchase of necessary materials (e.g., hotspot internet devices, tablets). Staff reported that low digital literacy was common among their older adult clientele, which contributed to significant time spent recruiting participants, fielding questions, and supporting participants. Staff reported that to properly support MOW clients, at least one part-time staff member was needed to coordinate program implementation and delivery. One MOWRI staff member described the Talking Tech coordinator as key to the success of the implementation of the intervention, stating, *"Once we moved [her] onto the project, I felt like we really kind of were able to better deliver on it. So, that was having a staff member that had organization and communication and management skills."* In addition to enabling MOWRI to dedicate a part-time staff member, funding ensured participant access to tablets and hotspot internet connections. By providing tablets and internet free of cost to participants, the intervention was accessible to the low-income, homebound older adult population that the organization serves. Program leadership noted that Talking Tech "*created an opportunity for [clients] to get connected by breaking down barriers, such as access to a computer or access to the internet*" (MOWRI Staff 1), and that the tablet was the "*biggest benefit*" because "*clients that participated and received the Surface Pro in all likelihood never would've been able to purchase such a thing on their own*" (MOWRI Staff 2).

Implementation Barriers

Challenges to implementation included the time- and resource-intensity of the intervention for MOWRI; data sharing restrictions across partners; participant and volunteer recruitment; and interruptions in program delivery due to the COVID-19 pandemic.

Organization staff reported that they had not anticipated how much time and effort would be required for implementation. MOWRI leadership stated:

> *"It was a very labor-intensive project. Coordinating the volunteers, the seniors, so on and so forth, that we would have been able to maybe do a little bit more if we had a full-time person really focused on the work" (MOWRI Staff 1).*

The Talking Tech coordinator described the program as "*much more time involved*" and "*a lot more daily work*" than they had anticipated due to "*all of the calls*" (MOWRI Staff 2). Recruitment calls were overwhelming not only because of the "*volume of calls*" but also because each conversation with a potential participant "*was a very long conversation*" due to the "*isolated and lonely*" nature of clients (MOWRI Staff 2). In addition to answering client and Talking Tech participant questions about the program, the Talking Tech coordinator reported that much of the unanticipated lift of the program

involved acting as additional technology support and functioning as a liaison between participants and volunteers. Additionally, the coordinator reported spending unanticipated time outside business hours resolving logistical issues arising from tablet set up and hotspot issues.

While collaboration between partner organizations was necessary to develop and deliver the program without requiring greater resources from MOWRI, issues with implementing data sharing processes led to data tracking and reporting issues that impacted efforts to assess participation in Well Connected and TechMate lessons. Changes in data privacy policies prevented Covia from sharing complete records of participants' Well Connected use. To remedy this situation, Covia asked TechMates to track participant use of Well Connected and tell participants to include the tag "RI" in their username to identify participation in Talking Tech. Inconsistency among TechMates in submitting weekly TechMate reports complicated MOWRI and the university study team's ability to track TechMate lesson completion. The Talking Tech coordinator described *"some confusion"* among TechMates regarding when TechMate reports should be submitted, and that while she was able to *"chase down"* some reports she did not have the time to collect all reports (MOWRI Staff 2). The university team then tracked completion *via* participant interviews for evaluation purposes.

MOWRI staff described participant and volunteer recruitment as the "*greatest challenges*" encountered during implementation and that they "*did not anticipate that we would have to work so hard at it*" (MOWRI Staff 2). While MOWRI had pre-existing clientele and volunteer pools, the organization struggled initially to identify clients who were interested in participating in a technology-based program. The Talking Tech coordinator noted that clients declined participating because they *"felt that they were just too old to learn something new,"* were *"hesitant to have a stranger in their home,"* or that *"they didn't want to make a commitment of meeting with somebody once a week"* because it was seen by clients as *"an extra responsibility,"* despite its design to be a benefit. Additionally, MOWRI exhausted many channels to recruit volunteers, including both within and outside of the organization. Staff reported difficulty "*getting enough people to sign up*" as volunteers (MOWRI Staff 2), despite having a large volunteer pool, in part due to the multi-week time commitment required of TechMates.

Due to the COVID-19 pandemic, many participants' training lessons were interrupted, and some stopped altogether. While MOWRI encouraged TechMates to continue lessons *via* telephone, many participants expressed disinterest in continuing lessons remotely during the pandemic. They preferred to either wait until the risk of disease transmission dissipated and social distancing restrictions were lifted, or they turned to family members for support.

> *"[W]hen the pandemic struck, we had to cease all in-person visits. Every TechMate was encouraged to continue the program via telephone. [. . .] For some clients, I don't know if they felt like they couldn't do it over the phone because that was just too difficult. They had a hard enough time understanding things in person" (MOWRI Staff 2).*

However, MOWRI staff noted:

> *"We discovered that [Talking Tech] was even more needed. During COVID-19, when Meals on Wheels recipients really didn't have any access to family members or friends, and we saw many more seniors at that point trying to access online resources" (MOWRI Staff 1).*

Lessons Learned

Interviews yielded a wealth of information regarding lessons learned. These included the importance of identifying successful participant and volunteer recruitment strategies to inform future recruitment efforts; using a targeted approach to identify potential participants and volunteers; incorporating flexibility into intervention design when working with the homebound older adult population; and monitoring the participant-volunteer relationship through TechMate reports to mitigate issues.

Findings suggest that a targeted approach to identifying appropriate participants and volunteers needs to be considered when designing a technology-based program. As a pilot intervention, the purpose of this study was to determine which processes, including recruitment methods, should be implemented in a larger intervention. MOWRI staff identified targeting clients with an email address and who self-reported as lonely was the most effective participant recruitment strategy. However, the study team found that some participants were hesitant to discuss experiences of social isolation or loneliness with the research team during surveys and interviews, highlighting potential challenges for targeting and engaging isolated or lonely older adults in this work. The Talking Tech program coordinator at MOWRI described the easiest clients to recruit as those *"who had already indicated that they were comfortable using the internet… and who were open to an additional opportunity for something that would make them feel connected to the outside world"* (MOWRI Staff 2). While challenges in recruitment were in part due to client hesitation, those who ultimately participated found free access to a computer device and online programming a strong incentive to join:

> *"The people who decided to participate and saw it as a very positive thing were floored that there was a program that was going to give them [a tablet]. They were very interested about the kinds of programming that they would have access to" (MOWRI Staff 2).*

Given the range of technology comfort and experience among TechMates, the Talking Tech coordinator suggested screening potential TechMates based on technology knowledge and skills, stating *"a volunteer pre-survey to give folks to judge their level of knowledge and comfort with technology would be good, especially considering that we looked to our existing volunteer base, which is largely older folks themselves"* (MOWRI Staff 2). Volunteers, participants, and MOWRI staff also supported the recommendation of having a dedicated on-call technology support personnel to consult for advanced technology issues. Such a resource would expand the technological expertise available to participants and reduce the amount of time the Talking Tech coordinator spent fielding participants' technology-related questions. One TechMate suggested, *"I don't know if*

there's a way to have a tech person who's assigned to this study that can help the participants. . . . That would be really great" (TechMate 2). As mentioned previously, two potential volunteers withdrew from participating after attending a training session because they felt that they would be unable to perform the technological tasks required of a TechMate, suggesting the need for targeted recruitment strategies and TechMate training evaluation to assess the effectiveness of training in preparing volunteers. While TechMates were asked about the effectiveness of training in interviews, no formal evaluation of TechMate training was performed in this pilot study. TechMates who were interviewed reported that the training was sufficient, however all three TechMates had extensive prior computer and internet experience.

Further, organizations should consider the aims of an ICT training program and who the corresponding target audience is in order to tailor recruitment efforts. The program coordinator noted that while a broader program goal may allow a wider reach, it may be more difficult to implement and evaluate compared to a goal with a specific audience in mind. While the specific goal of Talking Tech was to reduce social isolation and loneliness with a broader aim of increasing access to and use of technology, MOWRI staff stated that:

> *"The [participants] that felt most comfortable using the technology had used some form of the internet or technology before. The folks that were targeted for this, the most elderly folks who did sign up and who had never used the internet on their own or anything were the folks that really became easily frustrated" (MOWRI Staff 2).*

At the same time, the Talking Tech coordinator described needing to be flexible in the approach to working with homebound older adults. As many homebound organization clients have multiple chronic conditions that cause health complications, the coordinator reported participants canceling lessons with volunteers at the last minute due to health-related problems as a common challenge to carrying out training lessons. When working with the homebound older adult population, organizations should be cognizant of the additional barriers they face to participating in a weekly program and build flexibility into programs to accommodate participant needs. As the coordinator stated, "*[clients'] top concerns were being able to utilize [the tablet] and the difficulty associated with accessing the [Well Connected] programs,*" (MOWRI Staff 2), and as such volunteers should be prepared to address participants' technology concerns. TechMates described addressing clients' vision and dexterity impairments by changing font sizes and screen contrast and supplying stylus pens or computer mouses for those who were unable to use the tablet trackpad or touchscreen.

In addition to flexibility and accommodating needs, TechMates who were not prior MOWRI meal delivery drivers noted that training on communicating with older adults and making accommodations for participants with audio, visual, or mobility impairments would be helpful additions to volunteer training. One TechMate spoke to this need, saying:

> *"I had worked with older adults before [...] so I felt fairly comfortable working with that population. But maybe others who haven't worked with older adults much would benefit from some guidance. And then maybe going into someone else's home, how you kind of navigate that setting" (TechMate 3).*

While three TechMates were existing MOWRI volunteers who had received prior training and were accustomed to working with older adults in an individualized manner, these recommendations suggest that such interpersonal training is imperative for programs involving volunteers who work with older adults. For organizations with existing volunteer-based programs, volunteer-delivered ICT training programs can capitalize on or supplement existing volunteer training sessions.

Finally, MOWRI monitored the participant-volunteer relationships over the course of the intervention *via* weekly volunteer-submitted TechMate reports. These reports allowed MOWRI to identify emerging issues and intervene before escalation. For example, staff noticed *via* TechMate reports that one participant was becoming increasingly disengaged from learning as the intervention progressed, with the TechMate noting, *"She shows less interest as she considers it too confusing for her"* after the second lesson. The program coordinator was able to contact the participant, who ultimately decided to withdraw from the program, and reassign the TechMate volunteer to a new participant. The TechMate, who was highly engaged in Talking Tech, reported that this reassignment led to a rewarding relationship with their new participant and the participant's successful engagement with the program. In TechMate reports, the TechMate described the participant as *"excited about learning"* and that *"she responded well to instruction and is excited to do her 'homework' as she calls practicing basic use of the computer."*

DISCUSSION

This community case study reveals facilitators and barriers of implementing and delivering a community-based ICT training program for homebound older adults. We also include lessons learned and considerations for scalability and sustainability that may aid other CBOs in developing and implementing socialization programs for homebound older adults.

While social isolation and loneliness worsened during the COVID-19 pandemic (29), one study shows that frequent internet use during the pandemic buffered older adults against depression and declines in quality of life (30), suggesting that ICT training programs can address social isolation and loneliness in older adults both during and beyond the pandemic. The versatility of technology is a significant benefit of these interventions, as they have great potential for tailoring to individuals' specific needs. Prior research, as well as our own results, indicate that flexibility in program delivery is a necessary characteristic for successful technology training programs, as they allow for goal-motivated learning and individualization to accommodate participants' needs and abilities (31). To ensure flexibility and improve suitability and acceptance, programs

can incorporate the end user throughout program design and development (32, 33).

To be effective among older adults, technology-based interventions must also incorporate elements of supportive training and ongoing assistance to overcome barriers specific to older adults, such as lack of experience, technology illiteracy, and fear of using technology (21, 34). As our findings demonstrated, the impact of the COVID-19 pandemic on the ability to conduct in-person lessons highlights the importance of in-person technology training for older adults with limited digital literacy. In another technology training intervention, internet and device training and support improved older adults' confidence and competence in technology use (34). The success of ICT interventions with older adults is also dependent on high-quality communication. When online interactions are perceived to not be reciprocal or rewarding, technology use can lead to increased social isolation in older adults (18). CBOs wanting to implement ICT training programs should recognize that while many interventions have been effective in reducing social isolation, the technology itself does not alleviate social isolation.

Our findings highlight recruitment and adherence considerations. During the program design phase, organizations should consider the interests, needs, and experiences of the target population in concert with the resources and approaches available to deploy for recruitment. We found that a targeted recruitment strategy involving direct outreach to self-identified lonely clients with an email address was the most successful recruitment approach. In order to perform targeted recruitment, programs will need systems in place to capture participant characteristics of interest, such as internet or technology use or comfort, assessed here by having an email address, and possible loneliness or social isolation. To identify who may be the most likely to benefit from the intervention, CBOs should consider using a validated screening scale such as the Upstream Social Isolation Risk Screener (U-SIRS) (13) to assess social isolation in clients. The varying interest and success among MOWRI clients also suggest that an ICT training program such as the one described here may be most suitable for homebound older adults with prior experience using technology or a strong interest in developing these skills. Organizations should anticipate varying levels of willingness to learn how to use technology and comfort with technology among older adults [(35); Brazier et al., 2021, unpublished manuscript]. To improve older adults' willingness to adopt technology, CBOs can develop strategies to address factors known to influence adoption, including privacy concerns, perceived value of technology, perceived impact on quality of life, and confidence in learning a new skill (36). Additionally, disparities in access to technology among older adults should be considered, as inequities could influence receptiveness to and comfort with technology. The so-called digital divide, where access to technology is limited among older adults who are BIPOC, low-income, or reside in rural areas (25, 37), must be considered by organizations seeking to implement these services.

Considerations central to scaling and sustaining ICT training interventions include the cost and resources needed to deliver such a program, including physical materials, staff, and training. Talking Tech's use of a volunteer-delivered model can be scaled with program expansion as layperson-delivered interventions can be brought to scale more quickly than interventions requiring licensed professionals. CBOs must consider recruitment strategies and balance the demand for volunteers and the available resources for a 14-week intervention such as Talking Tech. The experience of MOWRI suggests that a part-time or full-time staff position is necessary to coordinate implementation and delivery of the program, as participants will likely reach out to the organization directly with questions or concerns. Given the issues and concerns faced by the Talking Tech coordinator, we recommend that an individual with a background in social work is best suited to coordinate an ICT training program.

Difficulties with tracking enrollment and Well Connected participation highlight the complexity of implementing an intervention involving multiple collaborating organizations. Data collection and monitoring challenges are common in health-related cross-sector collaborations, and overcoming these challenges are integral to success (38). In our experience implementing Talking Tech, navigating multiple data collection systems inhibited data sharing and monitoring between partners. In order to build the evidence base for effective social isolation and loneliness interventions and support evaluation efforts, securing financial support and expertise for integrated data collection and monitoring processes will be critical.

Limitations

One limitation of this pilot study is the small sample size of homebound older adults. However, as a pilot study reporting qualitative data, findings are not intended to be generalizable to other populations and are meant to be used to refine program development for future expansion. Additionally, interviews were conducted with only three volunteers and therefore may not capture the diversity of experiences among TechMates. Lastly, selection bias may have been introduced due to recruitment methods of participants and volunteers, as well as the absence of screening measures for social isolation, loneliness, and prior technology knowledge or use.

CONCLUSION

In light of physical distancing resulting from the COVID-19 pandemic, older adults may benefit from technology-supported social interactions. As community-based organizations and researchers seek to address social isolation and loneliness in homebound older adults, they must consider organization-level implementation facilitators and barriers to develop sustainable and effective programs. The facilitators, barriers, and lessons learned identified in Talking Tech can inform development and implementation of ICT training programs by other community-based organizations and researchers to support homebound older adults both during and beyond the pandemic.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

JB, LF, EG, and KT contributed to conception and design of the intervention program. JB, EG, and KT contributed to conception and design of the study. FJ acquired the data and prepared the manuscript. JB, ND, EG, and FJ analyzed and interpreted study data. All authors contributed to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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COMMUNITY CASE STUDY
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Alzheimer's Association Project VITAL: A Florida Statewide Initiative Using Technology to Impact Social Isolation and Well-Being

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Lack of social engagement and the resulting social isolation can have negative impacts on health and well-being, especially in senior care communities and for those living with dementia. Project VITAL leverages technology and community resources to create a network for connection, engagement, education, and support of individuals with dementia and their caregivers, and explores the impact of these interventions in reducing feelings of social isolation and increasing mood among residents during the COVID-19 pandemic. Through two phases, 600 personalized Wi-Fi-enabled iN2L tablets were distributed to 300 senior care communities (55% assisted living communities, 37% skilled nursing communities, 6% memory care communities, and 2% adult family-care homes) to connect and engage residents and their families. Different phases also included Project ECHO, a video-based learning platform, Alzheimer's Association virtual and online education and support for family caregivers, evidence-based online professional dementia care staff training and certification, and Virtual Forums designed to explore ways to build sustainable, scalable models to ensure access to support and decrease social isolation in the future. Tablet usage was collected over an 11-month period and an interim survey was designed to assess the effectiveness of the tablets, in preventing social isolation and increasing mood among residents during the COVID-19 pandemic. A total of 105 care community staff (whose community used the tablets) completed the survey and overall, these staff showed a high level of agreement to statements indicating that residents struggled with loneliness and mood, and that the tablet was useful in improving loneliness and mood in residents and allowing them to stay in touch with family and friends. Additional positive results were seen through a variety of other responses around the tablets and Project ECHO. Overall, the tablets were shown to be an effective way to engage residents and connect them with friends and family, as well as being a useful tool for staff members. A third phase is currently underway in the homes of people with dementia and their family caregivers, which includes tablets and direct access to Alzheimer's Association virtual and online education and support programs.

Keywords: Alzheimer's, dementia, technology, social isolation, COVID-19, tablets

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INTRODUCTION

Social engagement is an important aspect of well-being and cognitive health, especially in older adults (1–3). Conversely, the lack of social engagement and the resulting social isolation can have negative impacts on health and well-being (4–6). Nicholson (5) reviewed 74 publications and concluded that social isolation is an under assessed condition in older adults and has a number of detrimental outcomes including those that are physical, psychological, and physiological. Currently, it is estimated that 17% of adults aged 65 and older are socially isolated resulting in a 26% increased risk of early death due to subjective feelings of loneliness (7).

Loneliness and social isolation are an even greater concern for those in senior living environments. Severe loneliness is at least twice the rate for those in senior living communities than in the general community (8). Cudjoe et al. (9) found that isolation can impact both emotional and physical well-being of residents based on the decrease of social connections through events including geographic migration of children, relatives, or friends; death or disability among social network members; and personal factors including decline in physical or cognitive abilities.

In the recent face of COVID-19, the impact of social isolation in senior living communities has only increased with the social distancing guidelines, cancelation of group and communal activities, and closure to visitors, all resulting in a significant increase in isolation and the resulting loneliness felt by residents (8). The restrictions implemented during COVID-19 have disrupted the ability for residents to connect with their usual support systems and increased distressing behaviors and mood disturbance especially for those with Alzheimer's disease and related dementia (ADRD) (10). Additionally, Ray (10) suggests that during a crisis such as COVID-19, care community leaders and clinicians should be cognizant of the psychological well-being of residents as much as their chronic medical conditions.

To mitigate these risks and to support those in senior living communities, especially those living with ADRD, the potential utility of technology has increasingly been explored. A number of technologies have shown a positive impact on reducing social isolation, increasing quality of life, increasing positive emotions, and promoting greater level of activity and social engagement (11, 12). The purpose of this project is to assess the effectiveness of technology, specifically tablets, in reducing feelings of social isolation and increasing mood among residents during the COVID-19 pandemic.

CONTEXT

Project VITAL (Virtually Inclusive Technology for ALl) is a unique project that leverages technology and community resources to create a network for connection, engagement, education, and support of individuals with ADRD and their caregivers. This combination of components aims to positively impact social isolation, stress, and well-being. Originally launched in April 2020 with additional phases continuing into 2021, Project VITAL is a public-private partnership between Florida's Department of Elder Affairs (DoEA), the Alzheimer's Association, and other stakeholders, to help mitigate the effects of isolation during the COVID-19 pandemic and beyond.

Phase One (VITAL 1.0) included three components to impact connection, engagement, education, and support. The first included the distribution of 300 personalized tablets in 150 care communities to connect and engage residents and their families. The second component was Project ECHO (Extension for Community Healthcare Outcomes), implemented to facilitate educational and support opportunities for staff through a video-based learning platform. The third component was Alzheimer's Association virtual and online education and support for family caregivers in targeted underserved communities.

Phase Two (VITAL 2.0) rolled out in June of 2020 with an expansion to an additional 150 care communities and 300 additional tablets. VITAL 2.0 added two additional components. The first component was evidence-based online professional dementia care staff training and certification. The second component was VITAL Virtual Forums, designed to engage stakeholders in exploring ways to build sustainable, scalable models for increasing access to support and decreasing social isolation in the future for all Floridians.

VITAL 1.0 and VITAL 2.0 combined, involved a total of 300 care communities comprised of assisted living communities (55%), skilled nursing communities (37%), memory care communities (6%), and adult family-care homes (2%). Of these communities, 14% had 1–9 beds, 15% had 10–49 beds, 31% had 50–99 beds, 29% had 100–149 beds, and 11% had more than 150 beds. Each community had a lead contact and a back-up point of contact for the project who also completed the evaluation survey.

KEY PROGRAMMATIC ELEMENTS

iN2L Tablets

Tablets were a core component within the VITAL projects. The technology secured from iN2L were Samsung Galaxy tablets, pre-programmed with iN2L proprietary software aimed to facilitate connections between residents living with ADRD and families through various means. The tablet device was Wi-Fi-enabled and was created to be intuitive and simple to use and included security features to keep seniors safe during use. Residents and staff had no need for any previous smartphone or tablet experience. Staff received initial training and on-going support to implement the individualized programming and engagement with families. The interface provided simple touch access to an array of content specifically designed and curated for older adults, such as games, puzzles, trivia, music, sing-alongs, music therapy, audiobooks, movies and TV shows, virtual tours, history, and spiritual content. The tablets were also equipped with applications for direct video call connection to residents' family members, COVID-19 information and tips, and Alzheimer's Association programs, services, and resources. The tablets allowed content to be tailored to the residents' likes and interests and provided single touch connectivity for video calls.

Project ECHO

Project ECHO® was included as part of VITAL 1.0 and 2.0 and is an evidence-based distance-learning model that builds

workforce capacity to provide best practice care (historically in rural and underserved communities). In this model, a team of multidisciplinary experts come together with community-based partners in regularly scheduled collaborative learning sessions to participate in case-based discussions and hear experts present on best-practice care. Long-term care providers gain knowledge, confidence, and access to specialist consultation so that they can deliver excellent care to residents in their own care communities. Information flows in multiple directions: community care teams learn from specialists, specialists learn from community care teams on the front lines, and everyone learns from their peers.

Three separate learning cohorts completed five sessions each, and discussed examples from their care communities and had the opportunity to hear from other care communities facing similar challenges. Thirty-two assisted living communities signed up for the series and 15 completed the program.

Professional Training and Certification

The Alzheimer's Association Person-Centered Dementia Care Training Program educates professional care workers in long-term and community-based care settings on current evidence-based, person-centered practices to care for individuals living with dementia.

It is a self-paced, online training that provides 4 h of educational content and covers foundational information on Alzheimer's and dementia and four topic areas of the Dementia Care Practice Recommendations, which serve as the benchmark for quality care across the disease spectrum:

- Alzheimer's disease and dementia
- Person-centered care
- Assessment and care planning
- Activities of daily living
- Dementia-related behaviors and communication

After completing the online training program, staff have access to the Alzheimer's Association's essentiALZ®, an individual exam that demonstrates knowledge of quality care dementia practices. Staff who pass the exam are certified in essentiALZ for 2 years.

VITAL Virtual Forums

VITAL Virtual Forums were created to explore the complex reality of accessing care and decreasing social isolation specifically in Florida with invested and interested stakeholders. Attendees came together through Zoom to engage in virtual discussions and presentations and included caregivers, industry administrators, professional care providers, state aging units, and the general public. Three Project VITAL Virtual Forums (each 2 h) were held between August 2020 and February 2021 with an additional forum planned for August 2021.

EVALUATION

iN2L Tablet Usage

iN2L tablet usage data was collected as part of Project VITAL. The tablet usage data discussed in this article was collected over an 11-month period from May 2020 through March 2021. The May and June usage data included VITAL 1.0 data (150 communities; 300 tablets total), and July through March usage data included both VITAL 1.0 and VITAL 2.0 data (300 communities; 600 tablets total). The VITAL 1.0 and VITAL 2.0 data reported in this section use averages across the full 11-month period (May 2020–March 2021).

Overall Usage

Staff members provided residents with access to the tablets. Each resident could access their own profile with a simple passcode. This allowed the resident to initiate one-touch video calls, access their personal phonebook, view photos sent from family and friends, and access their favorite content. User sessions are defined as a distinct use of the tablet between a profile login and logout period. On average, a single user session included approximately three different activities (e.g., a video call followed by a playing game and then listening to music). There were an average of 4,140 user sessions per month with an average session time of 34 min. The average session time was calculated using a weighted average to account for differences in the total number of sessions each month. The weighted average was computed as follows:

$$\frac{\sum_{m=1}^{m} s_m * t_m}{\sum_{m=1}^{m} s_m}$$

where m = number of months, s_m = number of sessions in the given month, and t_m = average session time in the given month.

Video Calls

There were an average of 1,995 video calls each month with an average video call time of 7 min. The average video call time was calculated using a weighted average, as described above.

Content

The tablet has an extensive content library specifically for older adults, with more than 1,000 items that promote wellness and engagement and that can accommodate different levels of cognitive ability. There were an average of 10,343 content sessions each month with an average content session time of 14 min. The average content time reflects a weighted average, calculated using a procedure like the one described above. On average, 926 unique content items were accessed each month. The top 5 most popular content items across the 11-month period were (1) Puzzles, (2) Solitaire, (3) Therapeutic music, (4) Word Grid game, and (5) Bubble Popper. The tablets also include easy home screen access to the Alzheimer's Association's online educational content. This material was accessed on average 48 times each month. From May to October 2020, the tablets provided information on COVID-19 and during that time, that content was accessed an average of 466 times per month.

Interim Tablet Use Survey

The evaluation survey was designed to assess the effectiveness of technology, specifically the tablets, in preventing social isolation and increasing mood among residents during the COVID-19 pandemic. The survey was administered *via* Qualtrics to VITAL 1.0 and 2.0 care community staff members and included questions related to demographics, employment,

TABLE 1 | Staff perceptions on mood, loneliness, and tablet use (on a scale from 1 "strongly disagree" to 5 "strongly agree").

Statement	Communities without an ADRD unit		Communities with an ADRD unit—residents *without* ADRD		Communities with an ADRD unit—residents *with* ADRD	
	Mean	SD	Mean	SD	Mean	SD
Residents have been struggling with loneliness since the implementation of the COVID-19 precautionary measures	3.98	1.32	4.25	0.96	4.38	0.84
Residents' mood declined since the implementation of the COVID-19 precautionary measures	3.86	1.27	4.33	0.83	4.20	0.95
The iN2L tablets were useful in reducing residents' loneliness	3.93	1.15	4.13	1.04	4.28	0.92
The iN2L tablets were useful in improving residents' mood	4.09	1.01	4.20	0.95	4.31	0.90
The iN2L tablets made it easier for residents to stay in touch with family and friends	4.00	1.22	4.18	0.97	4.30	0.99
Residents enjoyed using the iN2L tablets	4.16	1.03	4.18	1.01	4.30	0.95
The iN2L tablets made it easier for residents to adjust to COVID-19 precautionary measures	3.61	1.02	3.93	1.01	3.87	1.06
Residents understood how to use the iN2L tablets	3.34	0.99	3.36	1.16	2.92	0.94
I had enough time to help residents with the iN2L tablets	3.55	1.27	3.70	1.02	3.64	1.14

ADRD, Alzheimer's disease and related dementias.

implementation of the tablet, and staff perceptions regarding effectiveness, training and support, ease of use, and acceptance. In care communities with a separate unit for ADRD (61 communities), staff perceptions regarding effectiveness were assessed separately for residents without, vs. with, ADRD. Staff members at participating care communities were invited to respond to the survey in two phases (VITAL 1.0 and VITAL 2.0). Staff were invited to participate in the survey ∼6 months after implementation. VITAL 1.0 staff received their invitation in November 2020 and VITAL 2.0 staff received their invitation in January 2021. Invitations were sent by email to community points of contact.

A total of 107 staff completed the survey. Two staff (one from a VITAL 1.0 and one from a VITAL 2.0 care community) indicated that their communities did not use the tablets and were excluded from analysis. In total, complete survey responses were available from 62 staff from VITAL 1.0 communities and 43 from VITAL 2.0 communities for a total of 105 staff responses. Responses were pooled across VITAL 1.0 and 2.0 care communities because an initial analysis indicated few differences by phase. The average age for staff in the survey was 49 years (SD = 12 years), and 91 staff identified as women, 12 identified as men, and 2 did not indicate their gender. Of all staff, 68 identified as White, 10 identified as Black or African American, 10 identified as Hispanic or Latino, 3 identified as Asian, 7 identified as Other, and 7 opted not to identify. On average, staff worked in their respective care community for 6 years (SD = 7 years). Sixty-four were activity directors, 19 were administrators, 11 held other positions, and 3 opted not to answer. Eleven staff had a master's degree, 44 completed a 4-year college degree, 15 completed a 2-year college degree, 22 completed high school, and 8 opted not to answer.

Table 1 gives an overview of staff members' perceptions regarding residents' adjustment to COVID-19 precautionary measures and effectiveness of the tablets. Sixty-one care communities had a special unit for residents with ADRD, while 44 did not. Data are provided separately by whether the care community had a unit for residents with ADRD, and if so, whether the responses applied to residents without or with ADRD. Overall, staff members showed a high level of agreement to statements indicating that residents struggled with loneliness and mood since the beginning of the COVID-19 pandemic. Staff also showed high levels of agreement to statements indicating that the tablet was useful in improving loneliness and mood in residents and allowing them to stay in touch with family and friends. Staff showed moderate levels of agreement to statements that the tablet improved residents' adjustment to COVID-19 precautionary measures, that residents understood how to use the tablets, and that staff had enough time to help the residents with the tablets. A series of paired-sample *t*-tests were performed to examine whether perceptions differed for residents without vs. with ADRD in communities that included a unit for ADRD. A significant difference was found (at $p < 0.05$, two-sided) for the statement concerning residents' understanding of tablet use, indicating lower levels of agreement that residents with ADRD understood how to use the tablets, $t_{(60)} = -4.40$, $p < 0.01$. This finding is not unexpected as the tablets are designed for staff to use the tablet alongside residents with ADRD. There were no significant differences in the agreement to other statements.

Table 2 gives an overview of responses regarding leadership, training and support, ease of use, acceptance, and recommendation. The leadership was stable in most care communities and was perceived as highly supportive of the tablets. Staff also indicated high levels of agreement that they

TABLE 2 | Staff perceptions on leadership, training and support, ease of use, acceptance, and recommendation.

Statement	Agreement	
	Mean or %	*SD*
Leadership (from 1 "strongly disagree" to 5 "strongly agree")		
Leadership changed in the last 6 months	17%	
Executive leadership supported the iN2L tablets	4.50	0.95
Training and support (from 1 "strongly disagree" to 5 "strongly agree")		
I had sufficient training on the use of the iN2L tablets	4.14	1.13
I had sufficient technical support on the use of the iN2L tablets	4.18	1.12
Ease of use (from 1 "strongly disagree" to 5 "strongly agree")		
The iN2L tablets were easy to include in our daily routines	4.00	1.14
The iN2L tablets were easy to use	4.23	1.05
Acceptance (from 1 "strongly disagree" to 5 "strongly agree")		
I enjoy using the iN2L tablets with the residents	4.46	0.93
I welcome the use of the iN2L tablets	4.58	0.87
Recommendation (from 0 "very unlikely" to 10 "very likely")		
How likely are you to recommend the iN2L program to friends and colleagues?	8.60	1.86

received sufficient training and technical support for the tablets, and that the tablets were easy to implement in daily routines and were easy to use. Staff showed very high levels of agreement to the statements that they enjoyed using the tablets with the residents and that they welcomed them. On average, staff indicated that it was very likely they would recommend the tablets to friends and colleagues.

Taken together, the results of this survey indicate that the tablets were perceived favorably by staff in VITAL 1.0 and 2.0 communities. Importantly, staff perceptions were equally favorable both for residents without and with ADRD. These findings suggest that the tablet may be a valuable tool to reduce social isolation and to improve mood in senior living communities.

Project ECHO

A post-survey was conducted with staff members who participated in Project ECHO. A total of 13 staff members completed the evaluation across the three cohorts from the 15 communities who participated and completed ECHO. It is not possible to determine if the 13 staff members were from 13 unique communities or not, which is a limitation of the design and should be addressed in future iterations.

All 13 staff members who completed the Project Echo evaluation were satisfied with the program, and found the information learned in Project ECHO was valuable in their work. In addition, 62% of participants made changes in the way they care for community members based on what they learned, and 78% said Project ECHO improved the quality of care they provide to community members with dementia. Lastly, 78% of participants said Project ECHO positively influenced the way they interacted with families and caregivers of community members with dementia.

Professional Training and Certification

Launched in January 2021 as a supplement to Project VITAL, the training and certification was met with interest from direct care workers in settings such as assisted living, home care, skilled nursing, adult day, and hospice. As of April 30th, 452 people had completed an interest form for the Project VITAL essentiALZ training and certification. Deployed in cohorts, the March 1st cohort had 150 participants, the April 1st cohort had 100 participants, and the May 1st cohort had 75 participants. The goal is to train and certify a total of 1,200 professional care providers.

To date, 141 individuals of the 325 in deployed cohorts have completed the training and certification and have submitted their evaluation. The other 184 individuals had not yet completed the training and certification, and thus did not have access to the evaluation at the time data were analyzed. Of the 141 individuals who completed the evaluation, 125 responded they were very satisfied with the training, 9 were somewhat satisfied, 4 were very dissatisfied and 3 opted to not respond. In addition, 112 of the 141 strongly agreed the training gave them important information about how to give person-centered care, 17 somewhat agreed, 3 neither agreed nor disagreed, 2 strongly disagreed, and 7 opted not to respond.

VITAL Virtual Forums

The VITAL Virtual Forums addressed the overview and progress of VITAL and included "Combating Social Isolation for at Home and Long Term Facility Care" with 389 attendees, "Florida Advocacy - A Vital Update" co-hosted by the Department of Elder Affairs with 117 attendees, and "The Road Ahead: Project Vital Update and Advocacy Events" with 160 attendees. No formal evaluation was conducted.

DISCUSSION

To effect positive change in the lives of individuals with dementia and the staff that provide care, Project VITAL 1.0 and 2.0 implemented customized, senior-friendly tablets in senior care communities, along with Project ECHO, virtual and online education support, and VITAL virtual forums.

The tablets were shown to be an effective way to engage and connect residents, as well as being a useful tool for staff members. The findings related to the tablets help demonstrate the value that purpose-built, senior-friendly technology can bring to older adults' lives, particularly in care communities. The tablet usage data demonstrates that residents used the tablets frequently and that they remained engaged with the tablet each time they used it. The usage seen here also speaks to the growing body of work showing that when older adults are given access to technology that has been designed specifically for them, they are interested, willing, and able to learn and use such technology (13–15).

Additionally, the tablets helped staff to proactively connect residents with their families without a significant impact on staff time, as well as address family's questions or concerns by allowing families to see residents through video calls. This technology-based connection and engagement can help provide families with ongoing confidence and comfort. The video call data suggests

that older adult residents are interested in using this technology to connect with others, provided they are given access to the tablet. To better understand the specific value of the video call feature for older adults, future evaluations may benefit from obtaining insights into who residents spoke with on video calls (e.g., are they repeatedly connecting with existing contacts; is their social network growing?) and/or the purpose of the video calls (e.g., connection vs. telehealth).

The content items that were accessed most frequently suggest that the tablets are commonly used for cognitive engagement and relaxation. The regular use of the tablets for such purposes has important implications. Engagement in cognitive leisure activities by older adults, which include puzzles and games, has been related to better cognition (16–18), reduced risk of dementia or cognitive decline [reviews and meta-analysis (19, 20)], and better mental health (16). Additionally, the prominence of games among the most popular content items likely speaks to the importance of design considerations for promoting adoption and use of technology in this population.

The COVID-19 pandemic has highlighted the value of technology, particularly for senior living operators who have increasingly recognized that technology is a necessity moving forward and not simply an amenity. A 2020 report by iN2L found a 60% increase in the number of senior living operators who think that engagement technology is extremely important now vs. pre-pandemic, and a 100% increase in the number of operators who see a definitive return on investment for engagement technology (21). Collectively, these findings suggest that technology needs to be ubiquitous and accessible across care communities to benefit the well-being of residents, families, and staff.

In addition to technology, Project VITAL included additional components to support person-centered care practices, more specifically engagement and connection. Professional training and certification provided the foundation knowledge of quality care practices based on the evidence-based Alzheimer's Association Dementia Care Practice Recommendations. Additionally, Project ECHO provided case-based learning and support as care teams made sustainable changes within their communities. Lastly, Virtual Forums engaged stakeholders in exploring ways to build sustainable, scalable models for increasing access to support and decreasing social isolation in the future.

There are a few limitations to note for this study. First, for the care community surveys, there was a relatively low response rate with 105 staff from the 300 participating care communities who used the tablets, which may limit the generalizability of our findings. The low response rate may be due in part to the design of the project, in which completing evaluations was not a requirement for participation. Although the staff responses still provide valuable insights, it will be important for future projects to incorporate a survey requirement for project participation. For example, it is possible that staff who were positive in their assessments were more likely to complete the evaluation than those who did not have good experiences with the program. Additionally, many staff members of these care communities have been overwhelmed by additional requirements and adjustments that have been needed to deal with the COVID-19 pandemic. As such, part of our lower response rate could be due to staff members feeling as if they do not have time to complete the survey. Second, staff responded with their perceptions of the residents' mood, feelings of loneliness, and table usage. It is possible that responses to these questions depend on how well staff know the residents. Third, as part of the project design, the surveys were anonymous. The survey included a question on the staff member's role/job title and whether their care community has a memory care unit, but there was not a question about the type of community they work at (e.g., assisted living) or more specifics about their residents (number, demographics, etc.). Thus, we cannot examine potential differences that may exist between community types, such as those that may arise from differences in level of care. Future iterations should collect such information to allow for comparison across groups. Fourth, we were not able to collect data prior to the implementation of the tablets. This would have allowed us to directly compare some measures before and after the implementation (for example, those related to the mood of residents and social isolation). Lastly, the lack of demographics and evaluation for the VITAL Virtual Forums impeded the ability to capture learnings and benefits. In the future, including demographics in the sign-up (including role, type of work, and community type) and a post-evaluation would be beneficial.

Given the positive findings from VITAL 1.0 and 2.0, the next question is whether such a program implemented in the homes of people with ADRD and their family caregivers can meaningfully impact social isolation, well-being, and stress. Accordingly, a third phase of Project VITAL is underway (Project VITAL At Home) in the homes of people with ADRD and their family caregivers and includes iN2L tablets and direct access to Alzheimer's Association virtual and online education and support programs. With nearly 60% of individuals living with dementia being cared for in the home (22), the impact of programs like Project VITAL can be monumental.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon request, without undue reservation.

ETHICS STATEMENT

Ethical approval for this study and written informed consent from the participants of the study were not required in accordance with local legislation and national guidelines. The University of South Florida IRB determined that the proposed activity did not constitute research involving human subjects as defined by DHHS and FDA regulations.

AUTHOR CONTRIBUTIONS

KH and SF contributed to the conception and design of the study. GH, LTN, RT, and LEP created the evaluation

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BRIEF RESEARCH REPORT
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Changes in Quality of Life and Loneliness Among Middle-Aged and Older Adults Participating in Therapist-Guided Digital Mental Health Intervention

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Background: This study aimed to examine the effects of a 12-week multicomponent mobile app-delivered intervention, the Meru Health Program (MHP), on mental health quality of life (QoL) and loneliness among the middle-aged and older adults with depression symptoms.

Methods: The eligible participants (M age = 57.06, SD = 11.26 years) were enrolled in the MHP, a therapist-supported mobile intervention. Using a non-randomized pre-post design, change in mental health QoL [WHO QoL Brief (WHOQOL-BREF) psychological health] and loneliness (UCLA Loneliness Scale) from baseline to post-treatment were examined. Time of enrollment [pre- vs. post-coronavirus disease 2019 (COVID-19)] was included as a between-subjects factor in the repeated measures analyses.

Results: Forty-two participants enrolled prior to the COVID-19 pandemic; eight enrolled after the pandemic began. Among the pre-COVID-19 enrollees, increase in mental health QoL, $F_{(1,38)} = 12.61$, $p = 0.001$, $\eta^2 = 0.25$ and decreases in loneliness emerged, $F_{(1,38)} = 5.42$, $p = 0.025$, $\eta^2 = 0.13$. The changes in mental health QoL, but not loneliness, held for the combined sample, such as post-COVID-19 enrollees, $F_{(1,44)} = 6.02$, $p = 0.018$, $\eta^2 = 0.12$. The regression analyses showed that increases in mindfulness were associated with the increased mental health QoL and decreased loneliness.

Conclusion: Therapist-supported digital mental health interventions, such as the MHP, have the potential to improve mental health QoL and decrease loneliness among the middle-aged and older adults. The findings for loneliness may not hold during the periods of mandated isolation. Instead, therapists supporting digital interventions may need to tailor their approach to target loneliness.

Keywords: aging, depression, digital health, digital therapeutics, mHealth, smartphone

INTRODUCTION

Loneliness, a subjective feeling of social isolation, afflicts more than a third (35%) of adults aged 45 and older (1). Furthermore, loneliness co-occurs with numerous chronic health conditions (2, 3), increases risk of dementia (4), and leads to increased morbidity and mortality (5, 6). The health epidemic of loneliness continues to worsen, most recently due to acute factors, such as the [coronavirus disease 2019 (COVID-19)] pandemic that led to or exacerbated social isolation (7).

The interventions targeting loneliness primarily focus on the enhancing social skills, providing social support, increasing social access, and/or targeting maladaptive thoughts (8). The meta-analytic findings suggest that the interventions that include components to target maladaptive thoughts or social cognitions were most efficacious (8). A review focused on older adults found that most of the interventions for loneliness were delivered in a group-based format (66%) and often utilized primarily educational interventions (9). The authors concluded that the interventions that promoted social connections were most effective (9). Moreover, the use of information and communication technology (e.g., social media and email) to foster connectivity among the older adults is gaining attention. The studies have demonstrated that greater access to and use of technology among the older adults is associated with lower depression, fewer chronic conditions, and greater perceived social support, health, and subjective well-being (10, 11). These findings suggest that the use of technology in late life can alleviate loneliness as well as support mental and physical health.

Aligned with the previous findings of the importance of addressing loneliness, the potential benefits of utilizing technology to promote social connectedness, and the inherent social connectedness in group interventions, we examined whether a multicomponent digital intervention may decrease loneliness. The digital intervention [Meru Health Program (MHP)] is a therapist-supported program that incorporates mindfulness and cognitive behavioral interventions to decrease depression and anxiety. Furthermore, the MHP is delivered in a group format with opportunities for social support through the therapist-moderated discussion among the group participants. Our previous work with middle-aged and older adults has demonstrated that the 8-week MHP program led to significant reductions in anxiety and depression (12) and subjective improvements in multiple domains, such as increased activity participation and improved social interactions (13). Furthermore, other work has shown that the skills incorporated into MHP intervention, specifically mindfulness skills, are found to reduce loneliness among the younger adults (14). Additionally, brief behavioral interventions, such as behavioral activation, are shown to decrease loneliness among the home-bound older adults with depression (15, 16). Taken together, it is expected that the MHP would both increase mental health quality of life (QoL) and decrease loneliness through increasing acceptance, improving self-regard/self-compassion, reducing negative cognitions, and promoting engagement in the present moment through informal mindfulness practices (17).

The present study aimed to extend previous findings on the benefits of the MHP on reducing depressive and anxiety symptoms to two important domains: QoL and loneliness. This study had two aims, which were to examine whether participation in the MHP resulted in change in (1) mental health QoL and (2) loneliness in a sample of middle aged and older adults with the depressive symptoms. In an exploratory aim, we investigated whether change in mindfulness was associated with change in mental health QoL and loneliness.

METHODS

Study Design

This study was a 12-week non-randomized pre-post examination of the MHP in middle-aged and older adults (Clinicaltrials.gov NCT03652948).

Participants

Recruitment of the participants occurred between April 2019 and March 2020 and between August 2020 and October 2020. The advertisements consisted of flyers posted on public community boards, newspaper advertisements, and digital advertisements (Craigslist and Facebook) targeting people aged 40 years and older within the California Bay Area. During the COVID-19 pandemic, digital ads on Craigslist and Facebook linked to a secure online contact survey became the primary source of recruitment between August and September 2020.

The eligible participants were the residents from California, with a smartphone capable of running the MHP app, and had increased depressive symptoms defined as Patients Health Questionnaire nine-item Scores $\geq$7 [PHQ-9; (18)]. Exclusion criteria applied during the initial telephone screen included presence of bipolar disorder, potential psychosis assessed using the Mini Neuropsychiatric Interview 7.0.2 [MINI; (19)] psychosis screening questions, substantial alcohol use as measured by the AUDIT-C [AUDIT-C $\geq$ 5; (20)], possible cognitive impairment as determined by the Short-Blessed Test [SBT $\geq$ 6; (21)], active suicide ideation [P4 Suicide Risk Screener; (22)], and participation in ongoing psychotherapy. The participants were allowed to enroll if taking psychotropic medications as long as they were on a stable dose for >30 days.

Measures

Demographics and Health Questionnaire

At baseline, the participants completed a demographics and health questionnaire that collected information about race/ethnicity, marital status, living situation, education, general health information, and eight health conditions (arthritis, asthma/bronchitis, cancer, diabetes, epilepsy, heart disease, hypertension, and stroke). Health conditions were tallied to create a variable capturing the total number of current health conditions.

Mini Neuropsychiatric Interview 7.0.2

At baseline, a trained study personnel completed a brief semi-structured psychiatric diagnostic interview, the MINI (19), with

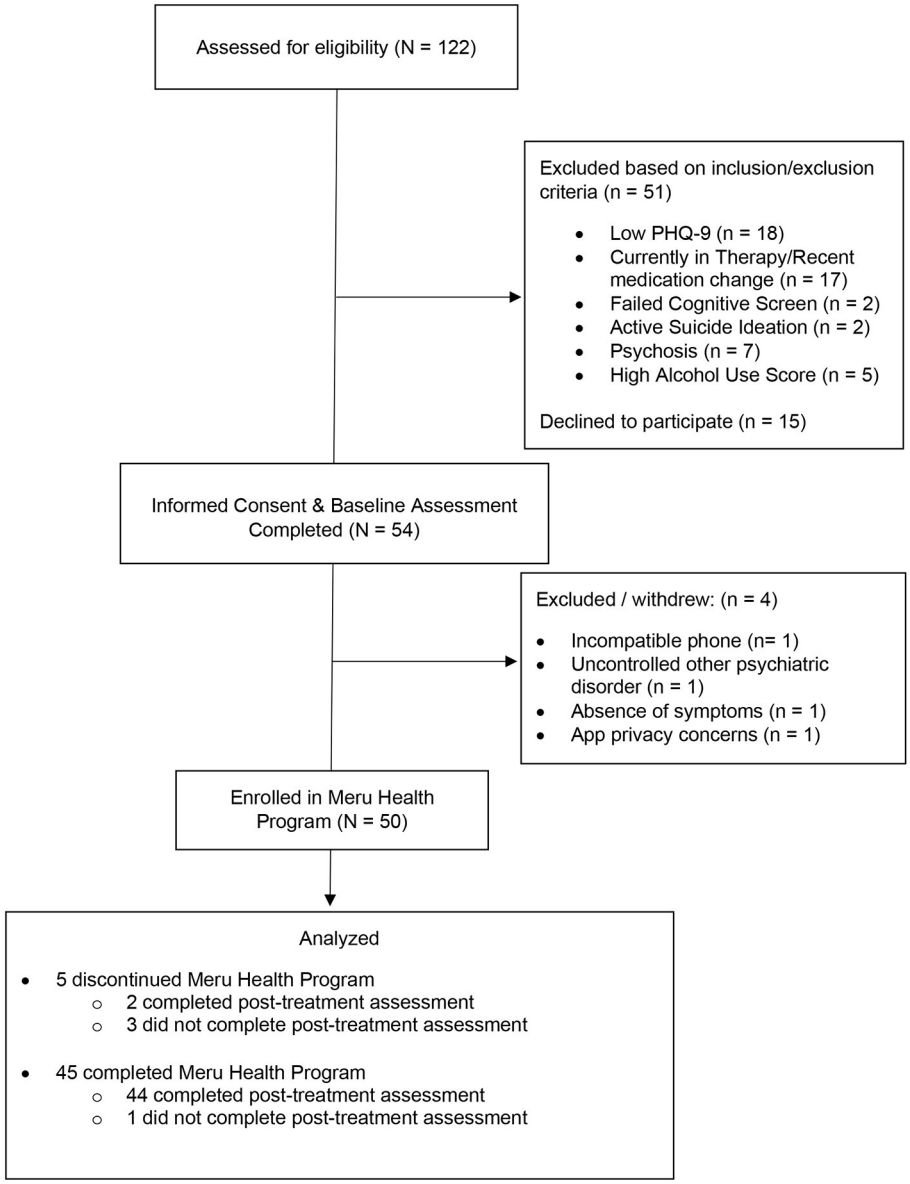

FIGURE 1 | Flow of the assessed and enrolled participants ($N = 50$).

the participants to identify the presence of current mental health disorders.

Patients Health Questionnaire 9-Item

The PHQ-9 (18) is a 9-item self-report scale that assesses the frequency of depressive symptoms in the past 2 weeks using a scale from 0 (not at all) to three (nearly every day). Higher scores indicate more severe depressive symptoms. The PHQ-9 has strong evidence of internal consistency, test-retest reliability, validity, and sensitivity and specificity for detecting depression (18, 23). Furthermore, it has been shown to be sensitive in detecting symptom change (23, 24). The PHQ-9 was administered at the telephone screen, baseline, week 5, week 9, and post-treatment.

Cognitive and Affective Mindfulness Scale-Revised

The Cognitive and Affective Mindfulness Scale-Revised CAMS-R (25) is 10-item measure of mindfulness that assesses attention, present-focus, awareness, and acceptance. The items are scored from one (rarely/not at all) to four (almost always) with higher scores indicative of more frequent mindfulness experiences. The CAMS-R has adequate internal consistency, and strong evidence of convergent and discriminant validity (25). Further, the CAMS-R has been demonstrated to be sensitive to change

TABLE 1 | The participant characteristics ($n = 50$).

Participant characteristics	*N* (%)	M (SD)
Age (years)		57.1 (11.3)
Education (years)		16.1 (2.9)
Sex		
Female	30 (60.0%)	
Male	20 (40.0%)	
Race/Ethnicity		
Any Race, Hispanic	3 (6.0%)	
Asian	8 (16.0%)	
Black	5 (10.0%)	
White, Non-Hispanic	29 (58.0%)	
Other	4 (8.0%)	
Marital status		
Single	17 (34.0%)	
Married	18 (36.0%)	
Separated/Divorced	13 (26.0%)	
Widowed	2 (4.0%)	
Employment		
Full-time	12 (24.0%)	
Part-time	13 (26.0%)	
Unemployed	12 (24.0%)	
Retired	12 (24.0%)	
Other	1 (2.0%)	
Number health conditions		
0	18 (36.0%)	
1	10 (20.0%)	
2	5 (10.0%)	
3 or more	17 (34.0%)	
Prevalence of current psychiatric diagnoses[a]		
Major Depressive Disorder	27 (54.0%)	
Anxiety Disorder(s)	21 (42.0%)	
Posttraumatic Stress Disorder	8 (16.0%)	
Binge Eating Disorder	7 (14.0%)	
PHQ-9		12.3 (5.5)
UCLA Loneliness Scale		50.9 (10.9)
WHOQOL-BREF		
Overall QoL and General Health	5.9 (2.0)	
Physical Health	21.5 (5.1)	
Psychological	17.2 (4.0)	
Social Relationships	8.5 (2.7)	
Environment	28.0 (5.7)	

[a] *Total does not equal 100% due to multiple participants exhibiting multiple diagnoses. Other psychiatric disorders account for <10%. Data shown are collapsed across the pre-coronavirus disease 2019 (COVID-19) and post-COVID enrollees.*

in the treatment studies (26). This measure was administered at baseline, week 5, week 9, and post-treatment.

WHO QoL-Brief

Developed by the WHO, the WHO QoL-Brief (WHOQOL-BREF) (27), has a total of 26 items related to five domains of quality of life: overall QoL and general health, physical health, psychological health, social relationships, and environment. Each item is scored on a scale of one (very dissatisfied) to five (very satisfied), thus higher scores indicated better QoL. Our variable of interest was the psychological health subscale, which is referred to as mental health QoL herein. This subscale contains items related to body image, the frequency of positive and negative feelings, self-esteem, spirituality, and thinking abilities (e.g., learning, memory, and concentration). This measure and its subscales have demonstrated good psychometric properties, such as discriminant and content validity, internal consistency, and test-retest reliability (27). The WHOQOL-BREF was measured at baseline and post-treatment.

UCLA Loneliness Scale

The University of California, Los Angeles (UCLA) Loneliness Scale (version 3; 28) is a 20-item measure of subjective feelings of loneliness and social isolation. The items are scored based on the frequency with which respondents perceive each statement to be self-descriptive. The scores range from one (never) to four (often), with higher scores indicating greater loneliness. The UCLA Loneliness Scale is shown to have good psychometric properties, such as high internal consistency, test-retest reliability, convergent validity, and construct validity (28). This measure was administered at baseline and post-treatment.

Procedures

Baseline Assessment

After determining eligibility through the telephone screen, the participants attended a baseline visit (in person pre-COVID-19, $n = 42$; over the telephone and *via* internet surveys after the COVID-19 pandemic began, $n = 8$). The participants completed questionnaires and partook in a semi-structured psychiatric interview (MINI). At the end of the baseline assessment, the eligible participants were provided with a brief overview of the MHP enrollment process. After the visit, a research team member referred the participant to Meru Health for MHP enrollment. The MHP therapist or clinical coordinator set up a time for the participant to have a brief intake call with the therapist. The participant completed standard questionnaires as part of the Meru Health intake process. The week prior to each group starting, the participants received an email with instructions to download the app and a unique link to sign into the app.

Intervention

The MHP v3.0 is 12-week mobile app-delivered intervention grounded in mindfulness and cognitive behavioral techniques. The MHP is delivered to a group of patients who work through the program as a cohort overseen by a therapist. The app delivers informational videos and guided practices that aim to help manage depression, anxiety, and burnout (stress). App content is delivered in the weekly themes that address topics, such as mindfulness, thinking traps, self-compassion, values, sleep, and nutrition. Additional program features include therapist (i.e., licensed marriage and family therapist or clinical social worker), and anonymous peer support from other group members. The therapist uses a dashboard to oversee the MHP progress of a patient. The therapist interacts with the patients by sending weekly informational emails, asynchronous secure messaging within the app, and conducting phone/video calls when needed. The peer support consists of therapist-moderated discussions that allow the group members to anonymously share thoughts and experiences with the practices. The group members can

respond to each other comments by selecting from a menu of pre-determined responses (e.g., "that sounds hard)." Beyond this study, MHP is available in the United States and Finland through employer-based wellness plans, insurance, and university-based mental health clinics.

Interim and Post-Treatment Assessments

The PHQ-9 and CAMS-R measures were collected at weeks 5 and 9 by phone or through secure online surveys according to the preference of participants. The measures, such as PHQ-9, CAMS-R, WHOQOL-BREF, and UCLA Loneliness Scale were completed after the participants finished the 12-week MHP (in-person $n = 29$; by phone/internet surveys $n = 17$).

Data Analyses

Descriptive statistics were utilized to describe the sample characteristics. Sample distribution kurtosis and skew were reviewed. The sample was determined to be normally distributed, so the parametric statistics were used. Using repeated measures ANOVA models, we examined change from baseline to 12 weeks for mental health QoL (WHOQOL-BREF psychological health scale) and loneliness (UCLA Loneliness Scale) for the pre-COVID-19 enrollees first. Next, these analyses were conducted with the entire sample, such as time of enrollment (pre- vs. post-COVID-19) as a between-subjects factor. Alpha was set at 0.05. The uncontrolled effect sizes using hedge's g were calculated.

Correlates of change were examined in the exploratory analyses. Change scores in mental health QoL were calculated by subtracting the baseline score from the post-treatment scores. For mental health QoL, positive change indicates improvements (i.e., increase in scores), whereas for UCLA Loneliness scores, negative change indicates decrease in loneliness (i.e., decline in scores). First, single-sample *t*-tests assessed whether the changes were significantly different from zero. Second, the linear regression analyses examined whether the baseline variables were associated with change in the dependent variables (mental health QoL and loneliness). Third, the linear regression analyses examined whether change in depression (PHQ-9) or mindfulness (CAMS-R) were associated with change in dependent variables (mental health QoL and loneliness).

RESULTS

Participant Flow and Characteristics

Fifty-four participants completed the baseline assessments; two were excluded (due to ineligibility) and two withdrew (due to improved symptoms and privacy concerns) prior to their MHP group start date (as shown in **Figure 1**). Thus, 50 participants with a mean age of 57.06 ($SD = 11.26$; range: 40–81 years) were enrolled in the MHP. About 60% ($n = 30$) of enrollees were female and the majority were white, non-Hispanic (58%, $n = 29$), followed by Asian (16%, $n = 8$), and Black/African American individuals (10%, $n = 5$). Mean baseline PHQ-9 scores were 12.28 ($SD = 5.47$) and fell in the moderate depressive symptom range (10–14). Regarding the baseline psychiatric diagnoses, two-thirds (66.7%) had either current major depressive disorder (28%; $n = 14$), an anxiety disorder (16%; $n = 8$), or both major depressive disorder and an anxiety disorder (26%; $n = 13$). Among the remaining third of participants, 19% ($n = 8$) had another current psychiatric disorder and 14% ($n = 7$) did not have any current psychiatric disorders. **Table 1** displays the participant characteristics at baseline.

Data collection and enrollment intersected with the historical event of the onset of the COVID-19 pandemic, which brought about shelter-in-place restrictions. Forty-two participants enrolled prior to the COVID-19 pandemic; eight enrolled after the pandemic had begun. The pre-COVID-19 enrollees were more likely to be married or partnered [$\chi^2(50) = 5.36$, $p = 0.021$], have lower baseline depression scores [$t_{(48)} = -2.10$, $p = 0.041$], and have higher baseline QoL-environment subscale scores [$t_{(48)} = 2.29$, $p = 0.027$], than post-COVID-19 enrollees. No baseline differences in mental health QoL or loneliness emerged.

Of 50 enrollees, 45 (90%) completed the 12-week MHP. Reasons for discontinuation of MHP participation were financial insecurity ($n = 1$), not liking the app ($n = 1$), work responsibilities ($n = 1$), and lost to follow-up ($n = 2$). Post-treatment data was obtained for 46 participants (92%). One completer did not provide a final assessment; two non-completers did provide a final assessment. The four participants who did not complete a post-treatment assessment (one completer; three non-completers) did not differ from the 46 participants included in the analyses on demographic characteristics or baseline depression symptoms, mental health QoL, or loneliness.

Change in Mental Health QoL

A repeated measures ANOVA examined change in mental health QoL among the participants who enrolled in the MHP pre-COVID-19. Significant increase in mental health QoL as measured with the WHOQOL-BREF psychological health subscale were found with a significant main effect of time, $F_{(1,38)} = 12.61$, $p = 0.001$, $\eta^2 = 0.25$. The uncontrolled effect size estimated using hedge's g was 0.44. A second repeated measures ANOVA was conducted for the combined sample that included a variable to compare pre-COVID-19 enrollees and post-COVID-19 enrollees as a between-subjects factor. In this analysis with the combined sample, the increases in mental health QoL held, with a significant main effect of time, $F_{(1,44)} = 6.02$, $p = 0.018$, $\eta^2 = 0.12$. Additionally, the main effect of enrollment was significant [$F_{(1,44)} = 4.70$, $p = 0.036$, $\eta^2 = 0.10$], which demonstrated that the mental health QoL for the pre-COVID-19 enrollees was higher than that of post-COVID-19 enrollees (as shown in **Figure 2A**). The interaction of enrollment and time was not significant [$F_{(1,44)} = 0.09$, $p = 0.770$, $\eta^2 = 0.002$], suggesting that the increased mental health QoL were similar for pre- and post-COVID-19 enrollees.

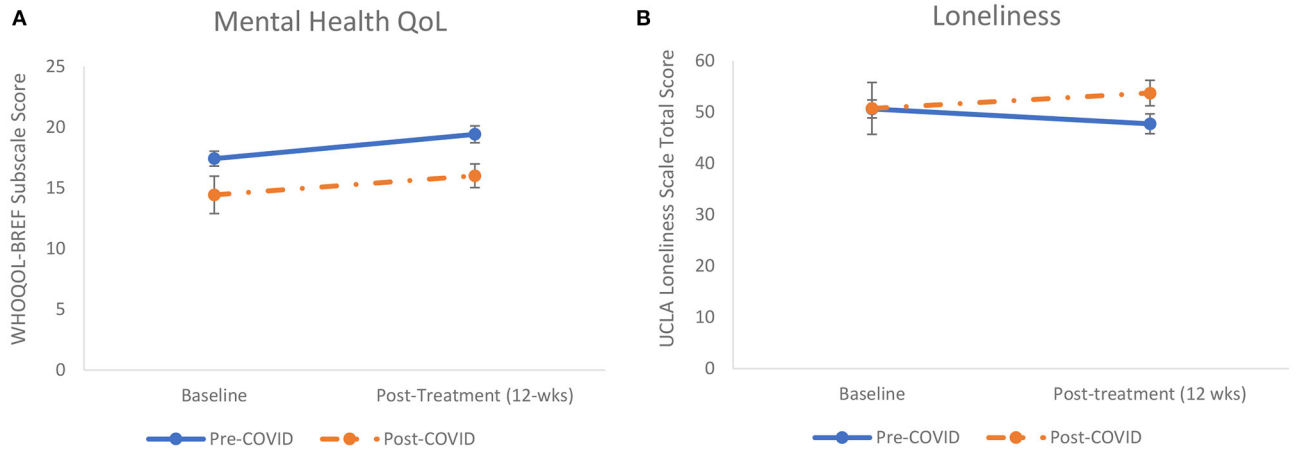

FIGURE 2 | (A,B). Increases in mental health quality of life (QoL) and declines in loneliness found from baseline to post-treatment ($N = 46$). **(A)** The increase in WHO QoL Brief (WHOQOL-BREF) scores represent significantly improved mental health QoL for pre-coronavirus disease 2019 (COVID-19) (solid line) and post-COVID-19 enrollees (dashed line). **(B)** The decline in UCLA Loneliness Scale scores represent significant decrease in loneliness for the pre-COVID enrollees (solid line). The dashed line shows a non-significant increase in loneliness for the post-COVID-19 enrollees. The error bars represent SEM.

Change in Loneliness

A repeated measures ANOVA examined change in loneliness among the participants who enrolled in MHP pre-COVID-19. A main effect of time emerged, demonstrating significant decreases in loneliness, $F_{(1,38)} = 5.42$, $p = 0.025$, $\eta^2 = 0.13$. The uncontrolled effect size estimated using hedge's g was -0.24. A second analysis conducted with the combined sample of participants enrolled pre- and post-COVID-19 found no significant main effects for time [$F_{(1,44)} = 0.001$, $p = 0.977$, $\eta^2 = 0.00$] or enrollment [$F_{(1,44)} = 0.49$, $p = 0.486$, $\eta^2 = 0.01$]. Moreover, the interaction was not significant, [$F_{(1,44)} = 2.88$, $p = 0.097$, $\eta^2 = 0.06$). As seen in **Figure 2B**, it appears that non-significant increases in loneliness occurred for the participants enrolled post-COVID-19.

Examining Correlates of Change

The initial step in examining correlates of change was to determine whether the change scores significantly differed from zero. For the pre-COVID-19 sample, change was significantly different from zero for both mental health QoL [$t_{(38)} = 3.55$, $p = 0.001$] and for loneliness [$t_{(38)} = -2.33$, $p = 0.025$). When including the post-COVID-19 enrollees, only mental health QoL was significantly different from zero. Consequently, the linear regression analyses focused on the pre-COVID-19 sample that displayed significant change in the dependent variables from baseline to post-treatment. Next, we conducted a regression model that included the baseline factors (i.e., PHQ-9 scores, current depression and anxiety diagnoses, gender, and age) as the independent variables. This analysis was not significant, indicating that the baseline factors were not significant correlates of change in QoL or loneliness (results not shown). Then, we examined whether change in the depression symptoms (PHQ-9) and in mindfulness (CAMS-R) from baseline to post-treatment were predictors of change in QoL and in loneliness. As displayed in **Table 2**, the regression analyses demonstrated that mindfulness had a positive association with improved mental health QoL (B = 0.43, $p = 0.004$) and a negative association with loneliness (B = −0.40, $p = 0.007$). Change in the depressive symptoms had a negative association with mental health QoL that approached significance (B = −0.29, $p = 0.048$). Change in the depressive symptoms were significantly and positively associated with loneliness (B = 0.34, $p = 0.019$).

DISCUSSION

These findings show that the MHP, a therapist-supported digital mental health intervention, was associated with increased mental health QoL and decreased loneliness among the middle-aged and older adults in a non-randomized pre-post study. Notably, the improvements in mindfulness across treatment were associated with increased mental health QoL and decreased loneliness. In contrast, the declines in depression symptoms only corresponded to the declines in loneliness. Taken together, these findings suggest that one mechanism through which the MHP may impact loneliness and mental health QoL is by improving mindfulness. The finding that the mindfulness component of this intervention may reduce the subjective experience of loneliness dovetails with findings of a recent dismantling study that demonstrated that the combination of present focus and acceptance skills from mindfulness resulted in the declines in loneliness compared with present focus alone (13). Nonjudgment and acceptance that is trained through mindfulness practice may help alleviate maladaptive thought patterns and emotions that accompany loneliness.

Although the future controlled studies need to replicate these findings, this investigation extends prior findings that support the reductions in psychiatric symptoms (12, 29–31) to QoL and loneliness. The improvement in mental health QoL likely correspond to the components of the MHP curriculum

TABLE 2 | The regression models examining correlates of change for pre-COVID-19 enrollees ($N = 38$).

Correlate	b (SE)	b 95% CI	Beta	*t*	*p*	R^2	Fit
Model examining change in mental health quality of life							
(Intercept)	0.16 (0.65)						
PHQ-9 Change	−0.22 (0.11)	−0.44, −0.002	−0.29	−2.05	0.048		
CAMS-R Change	0.33 (0.11)	0.11, 0.55	0.43	3.06	0.004		
						0.36	$F_{(2,38)} = 9.96, p < 0.001$
Model examining change in loneliness							
(Intercept)	1.40 (1.43)						
PHQ-9 Change	0.58 (0.24)	0.10, 1.07	0.34	2.45	0.019		
CAMS-R Change	−0.68 (0.23)	−1.16, −0.19	−0.40	−2.84	0.007		
						0.37	$F_{(2,38)} = 10.49, p < 0.001$

Two regression analyses are displayed. Higher scores on the mental health quality of life (QoL) measure indicate better QoL. In contrast, higher loneliness scores indicate more loneliness.

that target not only depression and anxiety, but also address the sleep difficulties and other mental health-related topics, such as relationships, self-compassion, values, and eating habits. Inclusion of therapist support likely contributes to the low dropout rate found in this study compared with unsupported digital interventions, which have higher drop-out rates and small treatment effects (32).

Loneliness negatively impacts physical, cognitive, and mental health and longevity, particularly among the middle-aged and older adults (2–6). Thus, the declines in loneliness following participation in a therapist-supported digital mental health intervention hold promise. Leveraging digital mental health interventions may be a critical step in increasing access to the efficacious interventions that older adults otherwise would not access due to scarcity of trained geriatric mental health providers (33). Further research is needed to examine the MHP and similar interventions in the controlled studies to better understand variations of intervention outcomes by age.

One important caveat to these findings is that when a historical event (COVID-19 pandemic) occurred, initiating shelter-in-place requirements for many participants, the decline in loneliness no longer held. The increase in mental health QoL remained significant regardless of shelter-in-place status, which highlights the potential benefits of using the digital mental health interventions for the middle-aged and older adults. It is possible that restricting opportunities to socialize in person cannot be overcome by the digital mental health interventions that otherwise have the potential to decrease loneliness. Therapists supporting the mobile health (mHealth) interventions may need to tailor their approach during the COVID-19 pandemic by encouraging the patients to make video calls and explore possibilities of online interest groups and virtual meet-ups in order to mitigate loneliness. The group support aspect of the MHP has the potential to help participants with the feelings of loneliness and subjective isolation in their mental health-related struggles; however, our previous work has demonstrated that this component was deemed to be less helpful than the information provided within the app, the daily practices, and support of the therapists (12). In contrast, for the younger users, use of the group support feature in MHP predicted the declines in depression scores (29). It is possible that using preset responses for group members, while important from a safety, risk reduction, and confidentiality standpoint, may limit engagement with this feature and reduce the usefulness of the group support aspect of the intervention for the older users in particular. Further consideration into incorporating the meaningful peer interactions in mHealth interventions targeting older users is needed.

Several limitations should be noted. First, this study lacked a control condition, thereby preventing any analyses or conclusions regarding the effect of the MHP on mental health QoL or loneliness compared with other interventions. As our study was not a dismantling study, it is possible that other MHP intervention components, such as behavioral activation, could have led to these improvements as well. Second, our findings are limited by the small number of enrollees after the COVID-19 shelter-in-place restrictions were enacted. Third, a measurement of objective social isolation was not obtained, thus limiting the interpretation of the findings, particularly with regard to the differences among the pre-COVID-19 and post-COVID-19 enrollees. Fourth, the sample was relatively homogeneous, consisting of white, non-Hispanic individuals, thus limiting information that can be gleaned about the effects of MHP among other groups. Fifth, our study was limited to the participants who had access to a smartphone, thus potentially limiting generalizability of the findings to those with higher technology proficiency and higher socioeconomic status (i.e., those who could afford such a device).

Despite these limitations, this investigation provides preliminary support for the effect of a therapist-supported mHealth intervention on yielding mental-health related QoL benefits, such as reduced loneliness. The regression analyses suggest that the components of MHP targeting mindfulness may be particularly important in yielding these mental health benefits. This study further demonstrates that older adults may benefit from the digital mental health interventions, which may, in turn, increase their access to mental healthcare. Future studies are needed to examine whether tailored therapist support targeting loneliness may enhance the effects of digital mental health interventions on this growing problem.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because data will be available upon reasonable request with agreement from funder. Requests to access the datasets should be directed to Christine Gould, cegould@stanford.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Stanford University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study. During the COVID-19 pandemic, participants provided oral consent upon reviewing an informed consent document.

AUTHOR CONTRIBUTIONS

CG conceptualized the research question, designed the study, oversaw data collection, conducted analyses, and drafted the manuscript. CCa collected data and assisted with drafting of the manuscript. AA assisted with drafting the manuscript. CCh assisted with data collection and with editing the manuscript. MB and VF-H edited the manuscript. All authors contributed to the article and approved the submitted version.

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Reducing Loneliness Among Aging Adults: The Roles of Personal Voice Assistants and Anthropomorphic Interactions

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The perception of feeling lonely is an influential factor in determining quality of life among aging adults. As the US Census Bureau projects that the number of Americans ages 65 and older will double by 2060, reducing loneliness is imperative. Personal voice assistants (PVAs) such as Amazon's Echo offer the ease-of-use of voice control with a friendly, helpful artificial intelligence. This study aimed to understand the influence of a PVA on loneliness reduction among adults of advanced ages, i.e., 75+, and explore anthropomorphism as a potential underlying mechanism. Participants ($N = 16$) ages 75 or older used an Amazon Echo PVA for 8 weeks in an independent living facility in the Midwest. Surveys were used to collect information about perceived loneliness, and PVA interaction data was recorded and analyzed. Participants consistently exceeded the required daily interactions. As hypothesized, after the first 4 weeks of the intervention, aging adults reported significantly lower loneliness (baseline mean = 2.22, SD = 0.42; week 4 mean = 1.99, SD = 0.45, $Z = -2.45$, and $p = 0.01$). Four dominant anthropomorphic themes emerged after thematic analysis of the entire 8 weeks' PVA interaction data (Cohen's Kappa = 0.92): (1) greetings (user-initiated, friendly phrases); (2) comments/questions (user-initiated, second-person pronoun), (3) polite interactions (user-initiated, direct-name friendly requests), (4) reaction (user response to Alexa). Relational greetings predicted loneliness reductions in the first 4 weeks and baseline loneliness predicted relational greetings with the PVA during the entire 8 weeks, suggesting that anthropomorphization of PVAs may play a role in mitigating loneliness in aging adults.

Keywords: loneliness, aging, gerontology, personal voice assistant, anthropomorphism, artificial intelligence, Amazon Alexa, conversational agent

INTRODUCTION

One of the most influential factors in determining quality of life among aging adults is the perception of feeling lonely (1, 2). Loneliness refers to perceived isolation or the sense of lacking companionship, and the negative feelings that can arise from not having a companion or emotional support, or a perceived lack of wider social networks (3–5). The experience of loneliness has

been associated with reduced opportunities for companionship, with older adults experiencing consequential social and emotional loneliness (6). Higher rates of depression, self-harm, self-neglecting behavior and mortality, as well as predictions of functional decline and death, have been associated with perceived loneliness (4, 7–9). Loneliness reduction is a pathway to improve aging adults' perceived life quality (2). When mitigated through technology such as Internet use, older adults reported improved quality of life (10). As the number of Americans ages 65 and older is projected to nearly double by 2060, to 95 million, the ability to reduce feelings of loneliness among aging adults in a cost effective, efficient manner is increasingly important (11).

Interventions to decrease loneliness in older adults have included companionship by ways of social facilitation, psychological therapies, health and social care provisions, animal interactions, and befriending, and increasingly, the introduction of information and communication technologies (ICT) (8, 12). These ICT interventions primarily involve training participants on an ICT device (most frequently, an Internet-enabled computer) and encouraging them to use the device to meet others, stay in contact with family, or engage in hobbies (10, 13, 14). Communication programs such as smartphones, iPads, email, and online chat rooms or forums, as well as technological innovations such as the Wii and virtual pet companions, have been found to have a positive influence on reducing loneliness (13). ICT interventions can reduce the cost of dedicated personnel visits and increase the opportunities one has for social connection; once the training period has ended, aging adults are free to use the device whenever and for as long as they desire. However, ICT devices, mainly computers and tablets, are restrictive to those who have difficulty typing, poor eyesight, or difficulty learning an unfamiliar system, which are common challenges in the aging adult population (15).

The introduction of personal voice assistant (PVA) devices or "smart speakers" such as the Google Nest or Amazon Echo provides a new opportunity for ICT intervention that may address drawbacks found in computer or tablet use. PVAs are essentially "voice assistants embodied in smart speakers" and have been labeled as "intelligent personal assistants, conversational agents, and virtual personal assistants" (16). These devices are highly accessible; they remove the physical requirements of viewing a screen and using a keyboard or touchscreen and are controlled by voice commands, which have been found appealing among older adults (15). Voice is quickly growing to become the predominant means of device interaction; 50% of searches were estimated to be done *via* voice in 2020 (17).

PVAs feature an interactive artificial intelligence (AI) that acts as an assistant who can respond, chat, or help at any time. While an AI cannot provide the same levels of conversation or support as a human visitor, research indicates that individuals view devices as possessing human-like qualities and can develop meaningful relationships with AI or other conversational bots (18, 19). This attribution of human traits to non-human entities is referred to as anthropomorphism (20). The phenomenon of anthropomorphizing AI technology is well-documented in both popular culture and research (21). There is also a strong body of evidence that humans anthropomorphize technology, including computers (22, 23), smartphones (24), cars (25), and robots (19, 26). Lonely individuals (i.e., those lacking social connection) are more likely to anthropomorphize non-human agents (27). One of the main motivations to anthropomorphize non-human entities is the desire to form social connections with non-human entities in the absence of humans (20, 28). Prior research demonstrated individuals who were more chronically disconnected from other humans were more likely to see their pets and other animals as having more traits related to social connection (e.g., thoughtful, considerate, and sympathetic) (28).

With the advent of PVAs, there is little surprise that people anthropomorphize PVAs as well (16, 29). Anthropomorphism for PVAs may be particularly strong, as PVAs are created to be social agents (e.g., a human voice from a PVA has been shown to increase social perceptions) (30). Adaptability, usefulness, enjoyment, sociability, perceived behavioral control and companionship are the variables that most indicate human acceptance of social robots, and PVAs are designed to exhibit all of these characteristics (31). With aging adults, as the number of relationships diminish, emotional connection through companionship strengthens with those remaining in a more limited social circle (32). In combination with relative affordability and accessibility, the AI-driven human voice and broad array of knowledge and programs make the PVA a prime candidate to create social connection—and in turn, elicit anthropomorphism—with the user. As a result, individuals who are lonely may turn to a PVA in order to gain social connection and feel less lonely.

Building on prior empirical studies of PVAs and aging adults which primarily focus on exploratory user experience such as how aging adults use PVAs (16, 33, 34) and how the PVAs provide companionship (35, 36), the current study aimed to investigate the impact of such PVA interactions on anthropomorphization and loneliness reduction. Despite commercial interests in PVAs and loneliness mitigation in aging adults from organizations such as the American Association of Retired Persons (37) and The Abbeyfield Society in the U.K. (38), there is a knowledge gap about PVA's efficacy on loneliness reduction and the pathway to such potential effects.

With voice commands becoming increasingly common and responsive, and intuitive AI becoming increasingly smarter, a PVA in the home could be a means of breaking through barriers of other ICT interventions and providing substantial benefits to an older population. Further, living alone could make aging adults, especially the understudied "older old" of adults 75+, particularly motivated to forge social bonds with AI technology. The Pew Research Center Social and Demographic Trends 2009 survey results suggest 75 is a significant turning point for older Americans (65 or older) to experience feeling old and other life changes such as "failing health, an inability to live independently, an inability to drive, difficulty with stairs" (39). However, there is limited existing research that investigates loneliness outcomes of PVA use among this population. The purpose of this study, then, was to explore the influence of a PVA on loneliness reduction among aging adults 75+ living alone, and the role of anthropomorphic interaction with AI. Therefore, we hypothesized the following outcomes regarding loneliness

reductions, anthropomorphization as a potential mechanism, and loneliness-driven anthropomorphic interactions:

H1: There will be significant reductions in loneliness among aging adults living alone in the first 4 weeks of the Alexa PVA intervention.

H2: Anthropomorphic interactions with the Alexa PVA will predict reductions in loneliness among aging adults living alone in the first 4 weeks of the Alexa PVA intervention.

H3: Baseline loneliness will predict anthropomorphic interactions with the Alexa PVA among aging adults living alone during the entire 8-week intervention.

METHODS

Study Design, Sample, and Procedures

This was a single-group quasi-experimental study design approved by the IRB. Adults 75 years of age and older were recruited from an independent living facility in the Midwest through flyers and informational presentations. In order to qualify for the study, participants had to live in their apartments alone (i.e., not with a spouse, relative or someone else), be fluent in English, have normative cognitive functioning (evaluated *via* an abbreviated mini-cognitive assessment over the phone (40), and could not currently own an Amazon Echo Dot or Google Home.

Researchers set up the Echo in participants' homes and trained them on how to use it. During the study period, participants were required to interact with the device at least five times each day, choosing commands from a provided list of 100 commands. The list was developed based on prior research about common uses of Alexa (41, 42). Selecting the commands allowed participants some agency and control, appreciated by older adults (43). Researchers monitored device usage, and gave reminders if participants did not meet requirements on days 7, 14, and 21. Starting at week 5, participants were allowed to use the device as much or as little as they wished. Such a study design ensures "minimal intervention needed to produce change" (44) will be met during the first 4 weeks *via* mandatory minimum interactions with the device while allowing participants to interact with the device voluntarily in a naturalistic way during the second 4 weeks.

To assess how participants used the PVA, it was important to have a time-stamped record of every interaction with the device and later be able to categorize the types of requests from the participants. These PVAs are designed by Amazon to record requests after hearing the wake word "Alexa," and send the requests to Amazon's secure cloud, where they are accessible through connected accounts (45). With participants' permission, each PVA device was linked with two accounts: the researchers' and the participant's. Only the participant had access to their participant account (i.e., researchers assisted them in creating the account, but participants created a password that the researchers did not know). Both accounts enabled access to device-usage data, which included every interaction the participant had with the Echo. As participants used their Echo, their usage data was recorded and linked to their account (e.g., if someone says "Alexa, what's the weather today" the device logged the time and what was asked). Following the conclusion of the study, the researchers copied all the interaction data from the device over the study period and then deleted the researchers account from the device, preventing them from seeing any future interaction data. Participants could continue to use their device uninterrupted through their participant account.

A manipulation check was performed to track the number of daily interactions to ensure participants had sufficient interactions with the device. In the first 4 weeks during which a minimum of five interactions were required, participants reported an average of 18 daily interactions with the device. During the second 4 weeks, they reported an average of 10 daily interactions with the device, even when no minimum interactions were required. Therefore, participants had sufficient interactions with the intervention device.

Measurement

Measurement consisted of survey items assessing perceptions of loneliness immediately before the study (baseline), after 4 weeks (week 4) of use, and a data log that recorded all participant interaction with the PVA during the entire 4 weeks. Participants' computer usage and usage of any apps on a smartphone in the week prior to the study were measured on a 4-point scale (1: <1 day, 2: 1–2 days, 3: 3–4 days, 4: 5–7 days).

Loneliness

Loneliness was measured by an abridged eight-item UCLA loneliness scale designed for remote assessment (16, 46, 47) immediately before the intervention and after 4 weeks during which participants were required to complete at least five daily tasks on the PVA. The items were assessed on a five-point scale ranging from one (strongly disagree) to five (strongly agree). Sample items include "I lack companionship," "There is no one I can turn to," and "I am no longer close to anyone" (reverse coded). Baseline and week 4 loneliness perceptions were each calculated by averaging the eight items. Cronbach's alpha was 0.77 for baseline loneliness and 0.67 for week 4 loneliness.

Anthropomorphic Interactions With the PVA

Anthropomorphic Interactions with the PVA for this study were determined using a thematic analysis, and operationalized as behaviors generally attributed to humans that demonstrated relational closeness, politeness, and interaction rituals. Anthropomorphic interactions were measured by extracting all recorded user commands among the 16 participating aging adults living alone and then coding for anthropomorphic themes during the first 4 weeks and the entire 8 weeks. The device-usage data recorded every interaction the participant had with the Echo. Only primary commands were included (incomprehensible commands, and deactivation and activation commands were excluded) (16).

Data Analysis

Descriptive statistics and normality tests (48) were performed for the dependent variables (i.e., perceptions of loneliness at the baseline and after 4 weeks of use). To test H1, a two-tailed Wilcoxon signed-rank nonparametric test was performed

TABLE 1 | Descriptive statistics and normality tests of perceptions of loneliness.

Variables	Mean	Median	SD	Skewness	Kurtosis	Shapiro–Wilk test
Baseline loneliness	2.22	2.31	0.41	−1.65, SE = 0.56	3.92, SE = 1.09	$W_{(16)} = 0.86, p = 0.018$
Week 4 loneliness	1.99	2.13	0.45	−1.16, SE = 0.56	0.09, SE = 1.09	$W_{(16)} = 0.81, p = 0.004$

at the 95% confidence interval to compare baseline and week 4 perceptions of loneliness.

To test H2 and H3, a thematic analysis (49) of the qualitative data from user interactions with the PVA was first performed to identify dominant themes and quantify individual anthropomorphic interactions under each theme. Using thematic analysis (49), anthropomorphic interactions were first extracted from all PVA interactions. Two coders looked for PVA interactions that exhibit behaviors generally attributed to humans that demonstrated relational closeness, politeness, and interaction rituals. A total of 901 anthropomorphic interactions were extracted. An inductive thematic analysis of anthropomorphic interactions (49) was then performed to identify patterned responses based on prevalence of repeated key words and significant meanings representing different types of relational closeness, politeness, and interaction rituals. Four dominant themes related to anthropomorphism emerged: relational greetings, comment/questions, polite behaviors and reactions. About 20% of anthropomorphic interactions were used to calculate intercoder reliability (Cohen's Kappa = 0.92). One coder coded the remaining data.

Theme (1) Relational greetings (user-initiated, friendly phrases).

This consisted of specific greetings to Alexa that one would typically use with a human companion. Participants' greetings included "Good morning," "Hello, Alexa," "Alexa, I'm going down for supper," "Alexa, I'm home," and "Good night."

Theme (2) Comments/questions (user-initiated, second-person pronoun).

This included interactions in which the user was speaking directly to the device, asking about it or addressing it as an actual person or being. Participants' comments and questions typically included using "you," e.g., asking "Alexa, how old are you?," "Alexa, what can you do for me?," "Alexa, do you have a poem you can quote for me that would relax me?," "Alexa, what are you thankful for?," "Alexa, I have been ignoring you, I'm sorry" and "You are in charge of the cat now, I'm leaving."

Theme (3) Polite behaviors (user-initiated, direct-name friendly requests).

This included terms with user requests or commands that reflected politeness norms typically incorporated in conversations with people. Participants' polite interactions included "Alexa, can I hear some harp music?," "Alexa, tell me a joke, please," "Alexa, please play some lullabies," or "Alexa, please let me know when it is four o' clock."

Theme (4) Reactions (user response to Alexa).

This consisted of verbal responses to Alexa's responses or feedback. Participants' verbal reactions included "That's very good," "I'm sorry, I can't think," "Alexa, that's enough," or "That was fun, thank you."

Anthropomorphic interactions in the first 4 weeks, along with prior computer use and app use, were entered as predictors of reductions in loneliness in a multiple regression analysis to test H2. To test H3, a multivariate analysis of variance (MANOVA) was then performed to estimate a single regression model with baseline loneliness as the predictor, and numbers of anthropomorphic interactions within each theme throughout the entire 8 weeks as the response variables.

RESULTS

Participant Characteristics

We conducted an 8-week within-subjects examination of $N = 16$ individuals, with ages ranging from 77 to 96 (M = 85.2 SD=5.02) living as the sole household resident. Of the participants, 69% were female and 31% male; 94% were white and 6% were black; and 12.5% had never married and 87.5% had been married.

H1 Loneliness Reductions

There will be significant reductions in loneliness among aging adults living alone in the first 4 weeks of the Alexa PVA intervention.

Table 1 includes a description of the baseline loneliness perceptions and the loneliness perception after 4 weeks of PVA use by the older participants.

Based on the Shapiro–Wilk test results reported in **Table 1**, the null hypotheses of normal population distributions for perceptions of loneliness were rejected for both baseline [$W_{(16)} = 0.86, p = 0.018$] and week 4 [$W_{(16)} = 0.81, p = 0.004$] perceptions of loneliness at $\alpha = 0.05$. The 2-tailed Wilcoxon signed-rank test showed that participants reported significant reductions in perceived loneliness after 4 weeks of using the PVA ($Z = -2.45$, $p = 0.01$; baseline mean = 2.22, SD = 0.42; week 4 mean = 1.99, SD = 0.45; see **Figure 1**), supporting H1.

H2: Anthropomorphization as a Potential Mechanism

Anthropomorphic interactions with the Alexa PVA will predict reductions in loneliness among aging adults living alone in the first 4 weeks of the Alexa PVA intervention.

Multiple regression was employed to examine the four themes of anthropomorphic interactions in the first 4 weeks as predictors of loneliness reductions during the same 4 weeks, controlling for prior week's computer use and app use in a single model. Overall the predictive model was significant, $F_{(6,9)} = 7.02$, $p < 0.005$, Adjusted R Square = 0.71. Participants' 4-week loneliness reductions were significantly predicted by the number of greetings ($\beta = 1.08$, $p < 0.05$). However, the number of

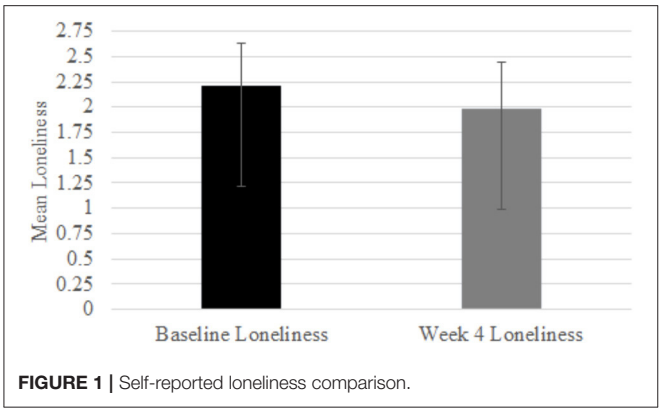

FIGURE 1 | Self-reported loneliness comparison.

reactions ($\beta = 0.10$, $p = 0.68$), polite interactions ($\beta = 0.03$, $p = 0.91$), or comments/questions ($\beta = -0.43$, $p = 0.25$) did not significantly predict 4-week loneliness reductions. Neither prior week's computer use ($\beta = -0.10$, $p = 0.61$) nor app use ($\beta = -0.39$, $p = 0.06$) predicted 4-week loneliness reductions. Therefore, H2 was partially supported: relational greetings to the Alexa PVA predicted 4-week loneliness reductions.

H3: Baseline Loneliness as a Driver for PVA Anthropomorphic Interactions

Baseline loneliness will predict anthropomorphic interactions with the Alexa PVA among aging adults living alone during the entire 8-week intervention.

MANOVA was performed to estimate baseline loneliness as the predictor of each of the four themes of anthropomorphic interactions in the entire 8 weeks in a single model.

Overall the predictive model was significant, Wilks' Lambda $= 0.40$, $F_{(4,11)} = 4.09$, $p < 0.05$, partial $\eta^2 = 0.60$. Participants' baseline loneliness significantly predicted the number of greetings, $F_{(1,15)} = 10.08$, $p < 0.01$, partial $\eta^2 = 0.42$, adjusted R Squared $= 0.38$ ($b = 43.34$, $p < 0.01$). However, participants' baseline loneliness did not significantly predict the number of reactions, $F_{(1,15)} = 0.31$, $p = 0.59$ ($b = 0.93$, $p = 0.59$), polite interactions, $F_{(1,15)} = 2.19$, $p = 0.16$ ($b = 10.08$, $p = 0.16$), or comments/questions, $F_{(1,15)} = 1.70$, $p = 0.21$ ($b = 8.53$, $p = 0.21$). Therefore, H2 was partially supported: baseline loneliness predicted relational greetings to the Alexa PVA.

DISCUSSION

This pilot study was designed to observe if PVAs can reduce loneliness for "older old" adults 75+ living alone and explore anthropomorphism as an underlying mechanism for loneliness reductions. The results provide preliminary evidence that a PVA can be regularly used by older individuals and may help reduce perceptions of loneliness within 4 weeks of use. We also found that baseline loneliness was the primary predictor to initiate friendly phrases to greet the PVA device during the 8 weeks of the intervention, suggesting that the lonelier an aging adult feels, the more likely she/he is going to treat PVAs as human, in anthropomorphic ways. Our findings are consistent with previous studies in which aging adults 65 or older personify PVAs by categorizing the devices as human-like and finding companionship through such interactions (16, 50). Results of the current study advance our understanding of PVA personification among aging adults by demonstrating the direct impact of such personification, i.e., as the aging adult anthropomorphizes PVAs, her/his loneliness subsides. In addition, our data illustrate a novel effect of baseline loneliness as an impetus for aging adults to anthropomorphize PVAs, perhaps as a mechanism to chip away isolation in her/his life.

As hypothesized, one of the main preliminary findings in this study was a decrease in the older adult participants' perceived loneliness after use of the PVA. This supports prior research suggesting that new technologies can provide promising opportunities for addressing loneliness in aging adults (51), and demonstrates how ICT interventions can significantly reduce loneliness, particularly among those studies involving communication, gaming, or virtual pet companions (13). A PVA can become a companion that one can actually communicate and/or play games with, and be entertained by (43). Participants were able to successfully use the device without major problems, completing an average of 18 daily interactions with the device in the first 4 weeks when a minimum of five were required, and an average of 10 daily interactions in the second 4 weeks when no minimum interactions were required.

Our findings also demonstrate that anthropomorphism of PVAs through relational greetings mitigated loneliness and baseline loneliness predicted relational greetings with the PVA. As noted earlier, anthropomorphism is often conceptualized as the attribution of human traits to non-human entities (20) and anthropomorphic interactions are typically driven by a user's desire to make social connections and form relationships with non-human entities (20, 28). The limited prior research that has been done about anthropomorphism and PVA use has supported how socioemotional states such as loneliness can drive anthropomorphism, and how polite terms and behaviors such as "please," "thank you," and "good afternoon" reflect personification of the device (16). This may be particularly useful information to positively impact loneliness in the cohort of adults aged 75+, which is representative of the sample used in our study.

While the coded usage data clearly indicate that participants were engaging with the device as an anthropomorphic agent in many different ways (i.e., reactions, polite language, comments/questions, and greetings), participants who were more lonely were more likely to seek out interactions with the PVA (i.e., not required to use the device) and initiate personal greetings (e.g., "Good morning," or "how are you today?"). These findings may be rooted in time of day and social activity; greetings/goodnights may be a distinct way by which more lonely individuals seek connection at times of day when the home is most likely to be empty. Greetings and goodbyes also represent interaction rituals, identified by Goffman as integral elements of social interaction, demonstrating regard and respect for those interacting (52, 53). When interacting with the PVA device, the user's willingness to follow social norms of politeness and interaction rituals indicates her/his respect for subtle social nuances when entering a relationship with the device. Relational closeness related behaviors, such as "Alexa, I am leaving. You're

in charge of the cat now," are clear signs of a user's desire to personally connect with the device. All of such behaviors are indications of a user's desire to connect with the PVA on a personal level.

Limitations and Future Studies

Taking a step further from prior studies that examined how older adults interact with a PVA (33, 35), the current project investigated the impacts of such PVA interactions on health and quality of life outcomes by exploring how loneliness in older adults could be influenced by anthropomorphic interactions with a PVA. To our knowledge this was the first study to explore how loneliness in adults 75+ could be influenced by anthropomorphic interactions with a PVA. Focusing on PVA use among the "older old" of participants 75+ makes our data a valuable addition to prior studies that included "younger old" participants, aged 65+ (33, 35) and should be of interest to researchers and practitioners interested in gerotechnology during this advanced stage of aging. Due to practical reasons of recruiting in a small pool of advanced ages of older adults, i.e., 75 or older, we adopted a single-group quasi-experimental design, which is within the norm of technology-based health intervention studies (54). Since research recruitment was halted due to the COVID-19 pandemic, future studies should include a larger diverse sample, and a comparison group with PVA use over a longer time period. Use of the PVA could also include different types of interactions, incorporating interaction types that are evidence-based from prior loneliness interventions, and those that are personalized to the user. Like prior research, the participants in our study were largely female older adults (55). Future investigations should examine whether men and women interact with PVA devices in different ways, and whether this has a variable impact on loneliness. Although our sample included men and women, the sample size was too small to allow for meaningful consideration of potential differences.

This study used living alone as a proxy for potential loneliness, and did not screen out participants based on their levels of loneliness. It is possible that some individuals in this study were simply not that lonely; they have many opportunities for social interaction living in a community residence. Despite this, results still show a consistent effect for the PVA on loneliness perceptions. Future research can address this gap by adding inclusion/exclusion criteria for those who have increased loneliness. Finally, the unique study design, incorporating a combination of device usage data, repeated surveys over time, and real-world location in the homes of individuals rather than in a lab, also demonstrates potential for understanding ICT use and influence moving forward.

CONCLUSION

Our study breaks new ground by showing the direct impact of PVA anthropomorphization on loneliness among this understudied, older 75+ population. Results indicate that as the aging adult anthropomorphizes PVAs, her/his loneliness subsides, illustrating a novel effect of baseline loneliness as an impetus for aging adults to anthropomorphize PVAs, perhaps as a mechanism to chip away isolation in her/his life. Our data demonstrate how engaging with an affordable, out-of-the-box technological innovation like the Amazon Echo can help reduce loneliness in older adults. It further suggests that the "older old" of 75+ year olds can have positive attitudes toward and demonstrate interest in using technological innovations to deliver interventions. In fact, many participants continued to use the device through the COVID-19 pandemic, demonstrating its potential as a longer-term loneliness intervention. While there is no "one size fits all" approach to addressing loneliness, and this type of intervention likely isn't right for everyone, the opportunity for participants to exercise control over and individualize the experience, drawing on thousands of commands and capabilities the Alexa AI provides, may enable a type of tailoring to the user that other technological innovations aren't able to provide.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because we do not have IRB approval to share the data. Requests to access the datasets should be directed to valeriejones@unl.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Nebraska Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

VJ and MH developed the grant and study, collected the data, and crafted the manuscript, with CY analyzing and interpreting data and results and contributing to the manuscript. MS and JB provided valuable insight, additions, and assistance on the manuscript. RMB provided great contributions as well, particularly in coding and interpreting the data. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.750736/full#supplementary-material

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Experiences of Older People and Social Inclusion in Relation to Smart "Age-Friendly" Cities: A Case Study of Chongqing, China

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Whilst cities can be sites of creativity, innovation, and change, they can also reproduce the conditions for the exclusion of vulnerable groups. Older people report experiencing specific barriers to accessing the city and are often excluded from the resources for ageing well. The smart city agenda has attempted to bring about technological change whilst also delivering improved quality of life for urban citizens. Smart technologies are a key element of the smart city and are viewed as having the potential to support the independence, autonomy, and well-being of older people. Yet, there has been little research exploring the role of the smart city in supporting the social inclusion of older people, nor any attempt to link this with key policy drivers on ageing e.g., age-friendly cities and communities. In response, the aim of this paper is to explore the experiences of older people living in a smart city in China and discuss how the smart city and age-friendly agenda can be brought together to support positive social outcomes for older people. The paper presents qualitative findings from a multi-methods approach, including semi-structured interviews, walking interviews and focus groups. A total of 64 older people participated in the research across three diverse neighbourhoods in the case study smart city of Chongqing, China. The findings identified opportunities in the development and deployment of smart city, including the potential for improved health and well-being and social connectedness. Yet in delivering on these benefits, a number of challenges were identified which may widen social inequalities, including inequities in access, issues of safety and security, and exclusion from the co-production of smart city policy and practise. The paper discusses the implications of the findings for future smart city policy and practise, specifically in delivering interventions that support older adults' social inclusion and the delivery of age-friendly cities and communities.

Keywords: smart cities, urban communities, ageing, social inclusion, age friendly city, smart technology

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INTRODUCTION

Smart Cities: A Creative and Innovative Response to Ageing and Urbanisation?

Innovative communication technologies enable us to share and communicate at a distance; the growth of infrastructure networks and the spread of digitisation of information have helped to speed up urban evolution in every aspect of society (1). At the same time, research has emphasised the meaningful role of cities as agents of global change and key elements in driving

social impact, often in unintended ways (2). Making the city smart is a relatively new urban development approach aimed at delivering sustainable urban environments through enhanced digital connectivity (3). Whilst there is no consensus on the definition of a smart city (4, 5), principles of sustainability, inclusivity, and integration are closely entwined. For example, the British Standards Institute (BSI) described a smart city as "*the effective integration of physical, digital, and human systems in the built environment to deliver a sustainable, prosperous, and inclusive future for its citizens*" (6).

Smart cities, through information transformation, networks of participation and social engagement introduce a new and potentially radical approach to urban development and current planning practise (7). Information Communication Technology (ICT) and the processing of "big data" have the potential to transform the way in which we live and communicate and thereby impact everyday lives (8, 9). The desire to enhance the quality, performance, and interactivity of urban services is a strong motivational factor, as is the drive to improve city infrastructure e.g., housing, transport, and outdoor spaces (10, 11). Yet, the deployment of the smart city agenda has also been heavily criticised, potentially opening up new forms of spatial inequalities as some groups remain digitally disconnected, and raising concerns about how smart cities can deliver inclusive outcomes for more vulnerable and hard to reach populations (12, 13).

Against the background of accelerated ageing and urbanisation, cities are seen as a hotbed for stimulating technological and social change (14). In delivering digital innovations, smart cities have the potential to respond to the twinned global trends of urbanisation and ageing which are shaping society and raising challenges and opportunities for how we design sustainable and equitable urban environments (15). In order to do so, our cities and urban policies have to provide innovative solutions to support an ageing population, providing essential interventions to meet the needs of older people while enhancing the well-being of older residents (16). The proportion of older people who are aged 60 and above is growing significantly (17). This is particularly the case for China where those aged over 60 comprise 264 million people, accounting for 18.7% of the total population (18). This number is expected to grow to 500 million by 2050. The country is also rapidly urbanising, with China's urban population growing from about 200 million in 1980 to about 800 million or 59% in 2018 (19). By 2030, the urban share of the population is expected to reach 70%, amounting to one billion urban residents (20) and of those urban populations, 1 in 4 will be older adults (21). The increasing ageing population is raising debates on how we can develop environments which best support older people to age well (22).

ICTs and smart cities are seen as having the ability to enhance active and healthy in older people by providing a creative and transformative approach (23). Combing smart cities and ICT technologies have the potential to provide a multi-dimensional and comprehensive solution to support older people in communities. The focus of such solutions is to support the creation and implementation of healthy, smart, and inclusive environments for older adults that enable them to actively participate in society while enjoying a healthy quality of life (23). Such solutions, which mainly include ICT-integrated smart homes (14), ambient assisted living (24) and home automation (25), are designed to facilitate active ageing and ageing-in-place through technological assistance. By creating new solutions and implementing best practise, the city with its aim of "go smarter" can optimise the potential of using the various capitals in cities and citizens, such as institutional, social and human capitals, and traditional (transport) and modern communication infrastructure (ICTs) (26), as well as integrating resources for supporting the participation of older people (23).

In response to the challenges of urbanisation and ageing, policy drivers, including WHO Age-Friendly Cities and Communities have explored how urban environments can deliver health and active ageing across key dimensions, including: (1) Outdoor spaces and buildings; (2) Transportation; (3) Housing; (4) Social participation; (5) Respect and social inclusion; (6) Civic participation and employment; (7) Communication and information; and (8) Community support and health services (27). Making cities and communities more age-friendly involves developing physical and social environments to meet the needs and requirements of older people while continuing to support older people to age-in-place (28). The WHO age-friendly framework have developed a number of associated guidelines and recommendations and the framework has been incorporated into region and country specific guidance e.g., WHO Europe and WHO Japan (29, 30). China has made similar progress, with Shanghai being a designated age-friendly city since 2006 (31) and recent announcements to launch 5,000 age-friendly communities by 2025 (32). In planning documents issued by the Shanghai Government (33), which aims to strengthen local age-friendly developments, it states that the local government will support the establishment of a IoT-related service platform for older people through providing online windows for government services. Additionally, the Shanghai government plans to build a number of standard age-friendly communities at a national-level by 2035 (34), in which it proposes to develop interconnected and sensory technologies in local communities. This will potentially enable local communities to interface with healthcare services and hospitals to assist in the development of age-friendly communities.

Despite this, there has been a lack of research explicitly linking smart city policy and age-friendly cities and communities. This is perhaps surprising, given the central role smart cities can play in developing interconnected monitoring technology (through the "Internet of Things") that can provide opportunities for supporting the health and well-being of older people (35, 36).

Building Linkages Between Social Inclusion, Ageing, and Age-Friendly Cities

Social inclusion is a key dimension of the age-friendly city agenda, underpinning the drive toward ageing in the "right" place which has highlighted the importance, not just of ageing at home and in the community, but having the resources and assets to

enable full participation in old age (27). The concept of social inclusion focuses on how older people can achieve their full potential (37); whilst addressing equity and rights in respect of access to services, social cohesion and community participation, including feeling respected and valued (27, 38). Whilst the notion of social exclusion has been criticised for prioritising the deficits of old age (i.e., what older people lack), the concept of "inclusion" prioritises ageing as a positive process (i.e., what older people can be) (28, 39, 40). Here, the emphasis is on creating the conditions for enhancing individual "joining in" or "identifying" with the social world (41) rather than merely avoiding social isolation.

Significant research in environmental and social gerontology has focused on social inclusion in the context of ageing, older people, and their everyday environments (28, 39, 40, 42). An age-friendly community views social inclusion as one that ensures older people's meaningful roles in society and provides opportunities to access resources, maintain relationships, and meet basic needs (28, 43). Social inclusion can support the improvement of physical and social outcomes for older adults, ensuring enhanced quality of life in old age (39). Scharlach and Lehning (42) suggested that social inclusion for older people can be supported across five key areas: (1) continuity (i.e., absence of barriers to continued participation in long-standing activities and interests); (2) compensation (i.e., the ability to meet basic health and social needs in spite of age-related disabilities); (3) connection (i.e., opportunities to develop and maintain meaningful interpersonal relationships); (4) contribution (i.e., opportunities to participate in and have an impact upon one's social environment); and (5) challenges (i.e., development of stimulating new activities and interests). Scharlach and Lehning (28) go on to identify the key components of social inclusion for older people: reciprocal social exchange that promotes interdependence rather than inequity and disempowerment; social integration that supports social identity; role fulfilment and maintenance of self-construction and self-esteem; social recognition from community members and themselves; meaningful social interaction; and social agency rooted in mastery, self-efficacy, and perceived control of oneself and one's environment (28).

Levitas et al. (44) refers to social exclusion as being one of social deprivation, in terms of lack of integration in community, participation in community and civic life and exclusion from the benefits others are entitled to such as lifelong learning and education. Social inclusion encompasses multiple aspects of ageing, such as civic engagement, outdoor spaces, social participation and supporting an ageing workforce as forms of everyday inclusivity (45). In providing opportunities for social inclusion within the context of an age-friendly community, it also constitutes supporting meaningful roles for people in old age (46). Research has identified the importance of enabling social inclusion for older people within the context of the age-friendly city, building social participation and engagement, developing strong social capital and connections and developing a strong sense of place identity and attachment in old age (40, 47). Supporting social inclusion amongst older people is therefore recognised as a key priority and goal for the age-friendly city.

Smart Technologies and Social Inclusion in the Context of Population Ageing

Smart technologies have been introduced in a number of ways at a home and community level to improve quality of life and independent living for older people, whilst offering opportunities for social inclusion (48, 49). At a city-level, technologies offer potential for the widespread diffusion of monitoring and sensor technologies to support transport delivery, mobility, and efficiencies in urban services *via* continuous and real-time monitoring (50, 51). In supporting an ageing population, Righi et al. (52) envisioned the potential for smart cities to deliver intergenerational urban communities through ICT interventions that are shaped around the interests and social practises of older people and which enable intergenerational connections to be formed. van Hoof et al. (35) identified how smart technologies can be deployed to support older people, e.g., health monitoring and emergency response systems, alongside assistance for activities of daily living in the context of the smart city. Others have highlighted the importance of scaling up what have been largely individually deployed interventions to date (e.g., body-worn sensor technologies) into an interconnected "city" scale approach thereby maximising what the smart city can offer (53). Likewise, advances in smart homes offer potential to support independent living, yet as van Hoof et al. (35) note, adoption is not widespread and lacks the connectivity across scales e.g., older people, carers, government, policymakers, which smart cities offer a potential framework for. As a result, smart city interventions to date have been limited in terms of realising their potential application for ageing and age-friendly cities.

In addition, there are a number of challenges in delivering technological products and services to older people (54, 55). Technological interventions have been relatively successful in responding to some of the functional needs of older adults, e.g., through medication reminders, but less so at delivering on broader challenges, e.g., those related to social inclusion including community engagement, social participation and equitability (56). Second, technological supports often fail to respond to the heterogeneity of the older person, both in terms of the ageing process and changing requirements across cultures in terms of what older people want from the technology (57). Third, the increasing Internet of Things (IoT) has raised new inclusion and equitability issues between who has access and who does not, and digital literacy which presents many from accessing online supports (58). The latter has been much discussed in the literature on smart cities and the digital divide (54, 55), pointing toward the "unevenly wired" and schisms between the "information rich" and "poor" (59). Reasons for the digital divide affecting older people vary but include: limited opportunities to accessing the internet (60); societal and individual attitudes impacting ICT use (49); physical health and learning disability barriers (61); socio-economic status and levels of deprivation (62) and differing interests in terms of what people want from the internet (63–65).

In summary, whilst there has been considerable policy rhetoric around the smart city, the role of older people, age-friendly environments and social inclusion in this agenda has received little discussion. Not only does this limit what can

be said about ageing, smart cities and inclusion in empirical terms, but also prevents us from shaping smart "age-friendly" urban environments which deliver improved social inclusion and well-being for older people. In response, the aim of this paper is to explore the experiences of older adults living in a smart city in China and to understand how social inclusion amongst older people can be supported in relation to technology development and smart city intervention. This is underpinned by the following research questions: (1) how is ageing in place and social inclusion experienced by older people living in a case study city in China?; (2) how do older people perceive technology and smart cities within their everyday lives?; (3) how can smart city interventions support the social inclusion of older people through the development of age-friendly cities and communities?

METHODS

This study undertook a case study approach in Chongqing, China to capture the experiences of older people living in a smart city. The city of Chongqing is located in western China, and it is one of four municipalities that is administered directly by the central government [(66), pp. 43–44]. By the end of 2019, the total registered population in Chongqing was 31.24 million, of which 4.674 million people were aged 65 and over, accounting for 14.96% of the total population (67).

During China's period of rapid urbanisation, the Chinese state has strategically promoted various models of urban development e.g., eco cities and low-carbon cities (68). Over the last 10–15 years this has focused on smart city development. In 2013, the Chinese Ministry of Housing and Urban and Rural Development (MOHURD) announced that 193 Chinese cities had expressed a plan to "go smart" while approving nearly 300 cities to pilot the smart city concept (69) of which the case study city, Chongqing, was proposed as a key city. Subsequently, in 2015, the Chongqing municipal government launched a Master Plan for supporting Chongqing's Smart City development, 2015–2020, and in 2019, the "Chongqing New Smart City Construction Plan (2019–2022)" was developed (70). In the Smart City Plan of Chongqing, Yuzhong district was designated a smart city pilot district, aiming to provide impetus for other national and regional strategic smart cities (71). Taken into account its geographic location, population density, background in terms of economic and cultural development and ageing demographics, Yuzhong District was selected as the case study site for this research. There are 580,000 people living in Yuzhong District, with 120,000 people aged 60 and above, accounting for 19.76% of the total population within the district (72). Compared to other pilot smart city sites, Yuzhong District has the highest proportion of older people.

The study undertook initial pilot work in February and March 2019 to build an understanding of the case study context and to apply and refine the data collection instruments. The main fieldwork was undertaken across December 2019–January 2020. The participants in this research represent older adults aged 60 and above, across three communities in Yuzhong District of smart city Chongqing: Shiyoulu Community, Hualongqiao Community and Dahuanglu Community. Three communities were selected based on the learning from the site visits and place observations which were conducted as part of initial pilot work. In the observations, we undertook an audit of the community including for e.g., quality of outdoor spaces, services and amenities, and other aspects of the built environment. Combined with desk based work, we selected three communities representing diversity in terms of their spatial and physical characteristics, ageing populations, income (low, medium, and high), smart city development (implementation pathways), housing types, and other physical characteristics including built environment supports (see **Table 1**).

The focus of this research was to understand how social inclusion amongst older people can be supported through smart city development. The research design utilised multiple qualitative research methods, including semi-structured interviews ($n = 69$; 23 older people and 46 professionals), walk-along interviews ($n = 21$ older people), and focus groups ($n = 20$ older people spread across three focus groups), undertaken with older people and stakeholders of smart cities. A total of 64 older people engaged in the research across three selected communities (mean age 72.57, age range 60–90, with 25 male and 39 female) (see **Table 2**). Participants ranged in terms of gender, ages, socio-economic background (low, medium, and high levels of income), health status, education, living status, and household composition. A further 46 semi-structured interviews were conducted with smart city professionals involved in either ageing policy and practise or the delivery of the smart city agenda, including local government officers, technology companies, service providers, private companies, and care providers. In this paper, we present findings from the semi-structured interviews, walking interviews, and focus groups conducted with older people to better understand the experience of older people living in a smart city.

All the semi-structured interviews with local older residents were undertaken at the initial stage of data collection. All interviews were conducted in a place of choice for older people, with the older people's activity centre and public gardens being chosen by most participants as they represented safe and familiar environments for older people. After the semi-structured interviews with older people, participants were invited to undertake walking interviews and focus groups. Some older people chose to walk with the researcher after the interviews, while others undertook walking interviews after the workshops. A small number of older people did not wish to participate in either walking interviews or workshops due to health-related problems, mobility issues or because of their busy schedules. Focus groups were organised with local older people in each local community, and comprising 6–8 local older people in each group. The first focus group was held at the local community centre in Shiyoulu Community, the other two were held in local ageing care service centres. Local ageing care service centres are owned by private companies and ageing care institutes, in partnership with the local government. They are places which

TABLE 1 | Comparative information across three case study communities.

Case study communities	Population	Population density	Population aged 65 years or over	Percentage of pop'n aged 65 years or over	Income	Public space and buildings	Smart city development
Shiyoulu community	71,154	22,462/km²	5,773	8.1	Medium	- Mix of old and new residential and commercial buildings; - Improved physical environment (e.g., sufficient pedestrian crossings, anti-slip signs, visual signs); - Lack of green space and public seating; - Residential exposure to transportation noise - Restricted pavement and mobility space.	Smart community at the national level
Hualongqiao community	15,806	4,718/km²	1,390	8.8	High	- Urban redevelopment area with new and modern residential buildings, mixed type retaining many historical and cultural buildings; - Proximity to amenities and services, including cultural supports; - Clean and well-maintained public realm and green space;	Involved in the district smart city plan
Dahuanglu Community	81,658	36,110/km²	7,915	9.7	Low	- Housing stock is dense and of poor quality, with limited green space and utilities/amenities. - There is limited number of public spaces for social, cultural and commercial activities, but they require maintenance and refurbishment; - Walkability difficult and pavement/sidewalk barriers problematic.	Involved in district smart city plan

provide caring services and assistive technologies to support older people living in the local communities. Interviewees did not receive any reward for their participation in the study. All interviews were audio recorded.

All audio recordings were fully transcribed in both Chinese and English and prepared for full data analysis. The full interview transcription files were analysed in Nvivo12 through a thematic analysis approach using the six steps adapted from Braun and Clarke (73). The first phase involved reading and re-reading the transcriptions in order for the researcher to familiarise themselves with the data. The second phase involved coding the transcripts for initial themes, and organising the data into different groups and codes. The third phase involved searching for themes and considering how different codes may combine to form overarching themes. The fourth phase re-focused the themes and double-checked how they inter-relate to the coded extracts. Finally, each theme was defined and named. The resultant themes and quotations are used to support the findings of this research.

Prior to commencement of the study, a full ethics review was approved by Heriot-Watt University's School of Energy, Geoscience, Infrastructure and Society Research Ethics Committee. Before beginning data collection, informed consent was received from all participants. Participants were made aware of the research aim and objectives, what is expected from them in terms of data collection, and how the data would be recorded and re-produced. Issues of confidentiality and anonymity were discussed with older people. The data collected was safeguarded and stored in password-protected files.

Findings

In order to understand how social inclusion amongst older people can be supported by the delivery of technological initiatives and smart city interventions, this research identified three key overarching themes through the interview data: (a) Challenges to Delivering Social Inclusion for Older People through Smart Cities; (b) Opportunities to Support Social Inclusion through Smart Cities; (c) Public Participation and (Dis)empowerment in Smart Cities; these were supported by five sub-themes (see **Table 3**).

Challenges to Delivering Social Inclusion for Older People Through Smart Cities

Reinforcing Social Exclusion and Inequality Through Smart Cities

Research has identified some of the concerns about smart cities delivering inclusive social outcomes for urban citizens (74, 75). Our participants discussed a number of barriers and challenges to the deployment of smart technology in improving the lives of older people. Many expressed financial concerns around smart technology use. While older people recognised the importance of technology in supporting ageing in place and health and well-being in old age, worries over their financial security were seen as

TABLE 2 | Sample of participant older people's characteristics.

		Chongqing, China		
		Dahuanglu community	**Shiyoulu community (smart community)**	**Hualongqiao community**
Semi-structured interview		10	6	7
Focus group		6	8	6
Walking interviews		6	7	8
N:		22	21	21
Age				
	Mean	74.91	72.8	70.0
	Min.	60	60	62
	Max.	90	86	84
	Median	75	73	69
Gender				
	Female	13	16	10
	Male	9	5	11
Living arrangements				
	Living alone	2	2	6
	Living with others	20	19	8
Employment status				
	Retired	20	15	20
	Employed	0	6	1
	Volunteer job	0	0	1
	Unemployed	2	0	0
Years living in area (unit: years)				
	Min.	0.08	5	2
	Max.	50	60	62
	Mean	9.76	26.0	8
	Median	10	17	5
Income status (GBP)				
	Max.	£555.56	£1,111.11	£666.67
	Min.	£8.89	£111.11	£222.22
	Mean	£308.89	£356.08	£407.41
	Median	£333.33	£333.33	£333.33
Landlord registration				
	Landlord	15	16	12
	Not landlord	7	5	9
Education				
	No qualification	5	3	0
	Low	2	0	2
	Middle	5	15	13
	High	5	3	6

1. Educational level is indexed on a four point scale (no qualification = non-educational; low = elementary education and lower vocational education; middle = secondary education and vocational education; High = college, university education, and scientific education).
2. Referring to the exchange rate on 9 MAR. 2020, 1GBP equals to 9CNY.

a significant barrier to adopting smart interventions. Here, older adults were concerned about technologies being available only for the "well off," potentially widening existing societal inequalities in old age:

> "I like smart technologies. They are great and important. I know it won't be a problem for those older people who have a high retirement income. But there are those who have a low retirement income, it will be a problem … it is a problem of financial income, certainly, the purchase of technology products are very expensive, the more intelligent products cost more. My family cannot afford it. You cannot say your family can afford; other families can, maybe he cannot." (Male, 78, Hualongqiao Community)

In addition to income and financial insecurity, a number of interviewees were concerned that smart city interventions would also open up spatial inequalities, creating an urban ("well-connected") and rural ("not well-connected") divide. Given the significant socio-spatial inequalities between urban and rural communities in China (76), digital interventions have

TABLE 3 | Themes and sub-themes from the thematic analysis.

Overarching themes	Sub-themes
Challenges to delivering social inclusion for older people through smart cities	Reinforcing social exclusion and inequality through smart cities
	Changing technologies, smart interventions and older people's requirements
	Insecurity arising from cybersecurity and privacy issues through using smart technology
Opportunities to support social inclusion through smart cities	Digital technologies to enhance social connectedness of older people
	Technology to support mental and physical health well-being of older people

Public Participation and (Dis)empowerment in Smart Cities.

the potential to "exclude" vast numbers of older people from accessing supports:

> "Yes, they are important [smart technology] and good. But I'm from a rural area, I don't have a retirement income, nor social pension. I'm living with my children and I eat whatever they buy for me. I have no income; I have no money. I cannot afford to buy these high-tech products." (Female, 63, Dahuanglu Community)

Exacerbating these spatial and social issues, older people were also concerned about the extent to which smart cities would lead to the commodification of products and services targeted at and potentially exploiting older people. Research has identified concerns about the role of private companies in commodifying services and products which may target vulnerable groups in the application of smart cities (77). As a result, whilst many pointed toward the benefits of smart technology, older adults were concerned they would be "left out" of the smart city agenda as a result of their material circumstances:

> "Yes, they are important [smart technologies]. It can measure blood pressure, locating where you are, and many other useful functions. But the quality has to be good too, to make sure of the accuracy of the result. But my biggest concern would be the price. I think they are very expensive. Most smartwatches cost 2000 Yuan (≈225 GBP), too expensive." (Female, 79, Shiyoulu Community)

Older people also felt that levels of education would determine ability to use smart technologies with the "less educated" being excluded. Participants argued that level of education amongst older adults directly affects their ability and interest in technology use, challenges which have been well-documented in the literature (78). Due to the impact of past political influences, the Cultural Revolution in particular, a number of older people have traditionally been excluded from educational opportunities (79). Many felt they were not in a position to learn smart technologies and to develop the necessary knowledge around them. This had the potential to open up a cohort and class divide excluding the most vulnerable older adults from accessing smart interventions and excluding many from lifelong learning opportunities:

> "You say that technologies, these are for people with higher educational background. Some older people can use it, but most of us cannot operate it. Especially people born in the 40/50s, we went to technical school at best. We do not enter university and receive higher education, we do not understand how to use technologies, we cannot use it [technology], cannot understand it [technology]." (Male, 75, Dahuanglu Community)
>
> "That [technologies], of course, it requires a certain amount of knowledge, I have not received any education, I am an uneducated person, then we will certainly not use it [technology]." (Male, 65, Dahuanglu Community)

In addition, older people pointed toward a number of key challenges in implementing smart cities: (i) low technological take up amongst older adults preventing adoption of interventions; (ii) difficulties in perceiving how smart technology might bring about health and well-being benefits; and (iii) poor levels of participation and engagement amongst older people in the development of the smart city agenda:

> "High-tech. we do not use these, and we do not understand what is that [smart technology]. Everyday of our lives, like today, is that we cook for ourselves, eating and watching TV ourselves. There is no high-tech. All day long, we do not participate in any social activities, and no one comes to inform us. (Female, 75, Hualongqiao Community)
>
> "I think they are very important, all aspects are very helpful to older people. But I have not been heard about this, neither been exposed to the local development [of smart technologies]. I don't care about them, I don't use technology all the time." (Male, 84, Hualongqiao Community)

In summary, our participants expressed a number of concerns about the deployment of smart cities and technologies, raising issues about their ability to bring about "inclusive" interventions for older people. In this sense, there remained considerable work to do in terms of reconciling smart cities with a socially sustainable agenda for older people in order to deliver opportunities for ageing in place.

Changing Technologies, Smart Interventions, and Older People's Requirements

In terms of older people's experience with accessing technology, older people argued that the design of technology did not often take into account the diverse requirements of older users. Many depended on others including family members to access online supports, raising concerns about the comprehensibility of technological supports, an issue which has been raised in the literature (80). A number of participants reported the need to be

"navigated" through technology (a "digital pathway") in order to access the services and supports they needed:

> "Technology is actually very good for our older people, but we have no one to teach us and no one to guide us… My child helped me making an appointment for visiting GP, but I can't get a specialist number. I don't use online registration, I don't know how to do it. It's all because we don't have anyone to guide us." (Female, 65, Dahuanglu Community)

Some older people reported that *"complicated"* and *"cumbersome"* technologies led to poor experiences when using technology, and often failed to support changing requirements in old age (81). Technologies and digital devices were seen as rapidly changing, which led to confusion and anxiety for many older people. Similar issues were encountered in terms of information and communication, with barriers to accessing technological supports in languages they could understand:

> "All I think of this is that the smartwatch I've used before. It can measure blood pressure, heart rate and so on. I used that before, but it was so much complicated to use, so I threw it away. Even the language is also English. I am a Chinese speaker, and I don't know anything about English. How can I use that watch?" (Male, 68, Dahuanglu Community)

Other participants felt excluded from using technology as a result of physical disabilities and cognitive impairment, groups of older adults who are already amongst our most isolated and disconnected (82). For those experiencing declining cognitive function, accessing technology and digital devices was complex, with some lacking the social support and training available to provide assistance. As a result, the following older adult living with mild dementia, reveals the challenges of using technologies:

> "My children come to visit me once a week. They usually give our lessons on using digital devices, like teach me how to use the phone. We want to learn how to use the smart phones like younger people do. But we cannot and it is very difficult to us to learn how to use. We, two old people, in the class we could understand some. However, every time after they leave, we forget quickly. We literally just forget how to use that device again. We always forget how to use it even though they already taught us." (Female, 73, Shiyoulu Community)

In summary, whilst technologies often form a ubiquitous and pervasive aspect of our everyday environments, there remains barriers and challenges to their uptake, and which prevent them from being adopted as part of an integrated part of everyday life. These barriers are compounded by mistrust in using technologies, and insecurities which are further heightened by issues of privacy and data use, which we discuss in the following section.

Insecurity Arising From Cybersecurity and Privacy Issues Through Using Smart Technology

The impact of digital surveillance has been widely discussed in the research raising ethical and political issues related to the security of individual privacy and data management (83). This has become more acute in the context of smart cities, given the potential for continuous data monitoring across urban environments (84). At the same time, concerns around data surveillance have been heightened in China as a result of moves toward using smart interventions to monitor and potentially control behaviours (85). In the interviews, some older people raised concerns about how technologies and digital settings can address the issue of data exposure and protect personal privacy. The privacy of users and confidentiality were determined as the most important aspect impacting older people making decisions on whether to adopt smart technologies and monitoring in the home:

> "Technology is important, but what if someone is monitoring me? I don't like being monitored and I won't agree to disclose my privacy." (Female, 75, Dahuanglu Community)

Whilst in-home surveillance theoretically supported health care, security, and independence whilst living at home, some older people felt uncomfortable and insecure in relation to the monitoring of in-home activities. Many who had used technologies previously, felt their activities and movement were being monitored and restricted. This raised serious concerns within the context of smart cities, and the integration of real-time monitoring on a wider scale:

> "I used security cameras before, I installed security cameras at home. It was originally used to monitor the kids, but instead put me under surveillance. I said to help me monitor now. Feel also embarrassed. I just don't like it. Why does it also monitor me? I don't like that … Imagine if this was on a city level. I don't want to disclose my private information to anyone." (Female, 76, Dahuanglu Community)

Feeling insecure is also reflected in perceived mistrust in terms of who is controlling, accessing, and using the information of online technologies (86). Due to a lack of digital literacy, older people reported that it was difficult for them to manage online for fear of being exploited and anxieties of being "watched" and "controlled," key concerns around surveillance and smart cities that have been identified in other research (87, 88). As a result, older people tended not to use the internet or digital access, calling for greater control over its deployment and use:

> "Yes, the market needs to be better regulated and require security regulation supported by the government. Every time I use my phone and try to access website, I literally do not know which one I can click, which one I cannot. For example, many times I hear on the news that fraudulent companies specialise in targeting and scamming older people.… Those information online, what is trustworthy, and what is not reliable, I am an old woman, I don't know. Sometimes, I just click the pages in a randomness, then it shows up, then we are cheated and caught up in the scam." (Female, 67, Dahuanglu Community)

In addition to the challenges of privacy and confidentiality in adopting technology, using technology and ICT at the scale of the city was new for many older people, resulting in a perceived

lack of confidence in using smart technologies. Some older people expressed feeling anxious about using smart devices ("fear of getting it wrong"), heightening feelings of insecurity:

> "For example, they say that we can give advice to the government online (e-governance), but I'm so afraid to click on those digital things. I actually envy those people who can use that (digital technology and application). But I'm not good in using those things and I can't use it. I have to learn, but I'm afraid I'll get it wrong and use it wrong. I have a headache when I think about using technologies." (Female, 75, Shiyoulu Community)

Moreover, compared to the younger generation, older people had less experience and exposure to AI and other information technology, whether it is self-driving cars or mobile devices. As a result, older people felt that they are more likely to encounter barriers and psychological challenges to accessing digital systems. Others were concerned that technologies which are ill-thought through would not afford older people the safety and security that they needed in terms of trusting the technology:

> "I've heard of self-driving cars, but I don't know how to operate them. And I think this car [self-driving] must not work in Chongqing, at least it needs another 10 years. The roads in Chongqing are very winding, climbing up and down, turning corners. Self-driving cars will take some time. And this technology is immature ah, there will be certain safety concerns. I'm afraid to use it now; after all, the technology is not mature." (Male, 69, Hualongqiao Community)

Taken together, the themes above reveal many ethical challenges and barriers to delivering social inclusion for older people through smart city interventions. These issues point toward the need to reconsider and perhaps reconfigure notions of security, privacy, safety, and ethics in the context of smart city interventions in order to ensure older people feel safe and secure.

Opportunities to Support Social Inclusion Through Smart Cities

Digital Technologies to Enhance Social Connectedness of Older People

Research has identified the potential social benefits and impacts of smart city interventions in terms of connectivity and mobility (89), but there has been no research exploring issues of social inclusion for older people. In identifying opportunities to improve social inclusion through smart city interventions, older people highlighted the importance of social participation and engagement as a key priority in terms of social well-being, including familial contact and social relations:

> "Technologies, such as smart phone, are important for me in my everyday life. It makes my life convenient. I love to play Mahjong with my friends. Like today, I want to play Mahjong and meet my friends. I then called my friends directly. Ask them if they can make an appointment this afternoon and just come and play Mahjong together.… Also, I need to connect with my family.… You need to hang out, travel, contact friends and families. Keeping contact with friends and families are important to me in every day." (Female, 65, Shiyoulu Community)

For many older people, smart cities have an important role to play in building connections and supporting older people to maintain meaningful interpersonal relationships. For example, in understanding what the main role of using mobile phones is for older people, participants emphasised that social companionship was important, through informal chatting, sharing images and news about day-to-day life events on social media platforms i.e., WeChat—a Chinese social media app.

In addition to the relational aspects of friendships and family, there was a specific role for technology in supporting everyday informal care in old age. This was related to activities of daily living e.g., sleeping, eating, and monitoring health and well-being alongside social support networks, suggesting a role for integrated smart technologies in linking informal care:

> "The other thing is that my daughter has given me a new smartphone and everyday I use it to talk to my friends. My children will contact me on the phone. They will ask each other, how are you, what are you eating, did you sleep well last night? It's time to put on some clothes today. And which classmates ah, like our age, classmates are still around, so classmates in the phone shouted to catch up, then we go and meet up." (Female, 87, Dahuanglu Community)

In addition to physical and social supports, staying connected to local services was deemed essential for older people and a key component of the age-friendly city, to ensure access to information and services. For older people, staying connected supported older people's sense of social engagement and feeling of security and safety:

> "The ones I mentioned earlier, like travelling, contacting relatives, safety are all sprinkled in. I have a mobile phone, for example, so if something happens to me, I can call the hospital, or I can tell my relatives, or my friends, and it brings lots of convenience to me. Whether it's physically or mentally, it certainly gives me a fair amount of help and support." (Male, 66, Hualongqiao Community)

Many participants identified the opportunities that technology can bring, reporting that using computers and mobile phones, particularly devices with interactive and communication-enabled applications brought opportunities to feel more included. Online networks can foster greater social interaction, particularly for those that are geographically disconnected (90). A number of older people in our study reported a sense of "being part of the outside world" as a result of technology, increasing happiness and well-being, and supporting ageing in place:

> Interviewer: "Do you think that smart technology contributes to ageing?"
>
> Participant: "It's very important. If you're connected to the internet now, you're basically connected to the outside world, and if you're connected, you don't feel lonely, because if you're at home alone, like you used to be, you'll get sick. If you're online

now, you have more friends, you talk more and you're happier." (Male, 60, Dahuanglu Community)

Participants also commented on the potential for using the internet and digital technology to access care services, medical advice and formal care in old age. Some older people felt that the internet and technology actively allowed older people to develop and maintain a close relationship with formal carers and healthcare practitioners. Thus, the smart city offers potential to deliver more meaningful interventions for older people if they are closely integrated with formal care (and in person, face to face) supports:

"In my case, that is to establish contact with community social workers and health care professionals to ensure good health. I have no one to take care of me and no children. If you get sick, you don't have anyone to take care of you, just like in some places, you die at home without even knowing. But here has volunteer services. The volunteers will come to visit once or twice a month. They will come to visit us once or twice a month and give you a talk, usually for an afternoon. They ask us what other needs we have, and they talk to us… you can call them if they are not feeling well. There is also a community-based family doctor who has come to our house a few times to see if we have any health problems, to see whether our blood pressure and blood sugar is high or not." (Male, 90, Dahuanglu Community)

In building a sense of connectedness, older people reflected that beyond access to ICT and digital information, smart devices and websites have expanded sources of access to knowledge and information. Many reported having widened their interests in later life, developing their intellectual curiosity in terms of local and global affairs, and had a real desire to improve their personal skills, competency, and literacy in old age:

"There is a role for smart technologies, that is watching TV, for example. By accessing information online and TV can increase the breadth of our social news, information and knowledge" (Male, 69, Hualongqiao Community)

"This is very important, my generation is fine, we basically know how to use it, nowadays mobile phones are very important, we are contacting each other online. Reading news online and learning information online" (Male, 60, Dahuanglu Community)

Through using technologies in everyday life, older people realised their benefits in terms of establishing and sustaining relationship with caregivers, friends, and relatives. This provides much needed security in old age in terms of ageing in place. By accessing digital information and smart technologies, older adults could feel a proximity to people and services. Therefore, a key challenge for smart cities is how to establish online networks that enable older people to promote reciprocal social exchange and foster interdependence.

Technology to Support Mental and Physical Health Well-Being of Older People

For our participants, feeling secure also included having access to resources and knowledge to make their own decisions about their health and well-being. Older people reflected on the value of digital technologies in providing mechanisms to enhance opportunities for older adults with mobility limitations to use digital devices to maintain quality of life. Self-management of health and well-being through technology is seen as an important in determining independence and autonomy in old age (91) and in using smart products, i.e., smartwatch and smart beds, which have features to measure blood pressure and heart rate, allowing for everyday monitoring (92). Amongst our participants, older people felt that taking effective actions to respond positively to their health conditions was empowering and a sense of security came through having knowledge of that information and being able to respond to it. This was an important aspect of social inclusion for older people:

"You know, like mobile phones, those phones can measure blood pressure and all that. My husband has high blood pressure, so I just take the phone to test his body and use these devices to estimate if he has high blood pressure or not, and he knows what his blood pressure is. If his blood pressure is high, he then would take some medicine quickly." (Female, 81, Dahuanglu Community)

"The economy is growing, technology has developed, and there are many benefits of using technologies. I see that the smart mattress can cheque blood pressure and physical fitness, which is very good, that brings lots of help for older people. Through these body tests, we can detect physical and health problems early and seek early medication and treatment from doctors." (Male, 84, Hualongqiao Community)

Many older people we interviewed encountered social exclusion often as a result of their restricted mobility. Declining physical health gradually led older people to spend more time at home, resulting in feelings of isolation and exclusion. For many this was related to the absence of opportunities for transportation and mobility. Participants stressed the value of smart technologies in supporting the age-friendly agenda, for example, through supporting mobility and maintaining the home. In supporting everyday tasks and overcoming physical barriers, older people reported that smart technologies could free up more of their time and opportunities for social participation and civic engagement. Despite this, many were still to see any real benefits or smart city applications in their everyday lives:

"The important thing is that you can buy a self-driving car, for example, if you want to go somewhere, you tell the car (self-driving car) and it comes to pick you up. Also, when the car arrives at our destination, the car will automatically notify us to get off." (Male, 75, Dahuanglu Community)

"If features of smart technologies can be achieved and applied to older people, of course, then these can help… such as robots can sweep the floor, do housework for us, those features are very good. But now we have not seen those things happened to us, our community does not seem to have seen those robots sweeping the floor." (Male, 70, Shiyoulu Community)

While older people reported feeling insecure and uncomfortable due to in-home surveillance, older people did report a flip side to this, in terms of enhancing security and safety. Smart technologies had a potentially positive role to place in enhancing

feelings of security e.g., through real-time detection, hazard warnings, emergency response, as well as everyday reminders. The fact that older people could "monitor and see" the technology was important:

> "If it's a smart home, if it's a burglar that comes into the house, the system will warn you and the police. Sometimes it also reminds you, for example if you go out and forget your keys, the smart device will remind you. It's just nice and convenient. If I put a camera in the house, at night when I'm sleeping, I turn this on at night. If a burglar comes in or something dangerous happens, I can know about it, and I can monitor it, I can see it." (Female, 87, Dahuanglu Community)

In addition to physical supports, older people also reported on the importance of mental health and well-being in old age. For many, smart technologies did not necessarily need to be integrated into homes and buildings to bring about benefits. The use of portable products such as mobile phones, smartwatches, wearable devices and robots had the potential to deliver advantages. For many, smart technologies for older people afforded a feeling of "companionship" and comfort in old age. Here, it was important that technology was able to develop a two way relationship with the older person, offering a range of physical and social benefits:

> "I have a robot, and there is a robot in my house. It's called "Meihao." Every time you shout "Meihao, Meihao! I want to listen a storey." and it will tell you a storey… But now it doesn't work because it needs internet support, it doesn't work without internet support. It's connecting to the internet, and when it's connected, it's ready to use. Call him to sing to you, and he will sing to you. When you are not feeling well, you can ask him what medicine you need to take. It will also tell you. He says, "You should go to the hospital and see a doctor." Then I would go to the hospital." (Male, 75, Dahuanglu Community)

For some, older people felt smart environments had the potential to support their everyday life by being able to diagnose and intervene in response to health conditions, which has been a key area in the development of technology for older people (93). Through connecting to medical services and GPs, smart devices facilitated more support, flexibility, and convenience in the lives of older adults:

> "If you are sick, you have to tell him (e-health service). The doctor will answer you, which medicine you should take, which place you should go, where you are not well. I went to buy medicine this afternoon and there was a computer doctor at the Pharmacy. When you see the computer doctor you just have to tell him what is wrong with you and where you are not well? The computer doctor will then tell you what medicine to take." (Male, 81, Dahuanglu Community)

In summary, smart technologies can provide opportunities for improving the social inclusion of older people, through supporting everyday tasks, enhancing a sense of security and facilitating social participation. Through improved connectivity, older people can receive physical support through using digital technology to maintain social connections, and ultimately contribute to the social inclusion of older people, improving access to supports and resources to age well.

Public Participation and (Dis)Empowerment in Smart Cities

Participants reflected on the issues of involvement and participation in the smart city agenda. In discussion on the progress of smart city development, older people reflected that there is neither the chance to participate in local development, nor has there been tangible improvements as a result of smart city initiatives. Whilst many had heard of smart cities, older people felt that smart city development had afforded little impact on their everyday lives:

> Interviewer: "Do you know there is a smart community in Shiyoulu, Yuzhong District? Can you feel the change?"
>
> Participant: "Yes. We know it. Our district has one as well. I heard that our universities and governments spent 30 million to build one. But I haven't felt any changes." (Female, 75, Shiyoulu Community)

There were few opportunities for older people to input into the decision-making process within communities, reflecting a lack of formal engagement opportunities as part of the smart city agenda. The lack of citizen engagement in smart cities has been noted as a shortcoming in the literature (94). Many felt as if they were not listened to and lacked knowledge of where to go to in order for their voice to be heard:

> Interviewer: "Can you make advice or suggestions?"
>
> Participant: "No. Nobody listens. Nowhere to speak, report and appeal. We cannot find that place." (Male, 67, Shiyoulu Community)

Due to the lack of consultation and engagement between older people and government, participants expressed a feeling of distrust toward the government. Many were sceptical as to the extent to which the policy around smart cities would be translated into actual practise:

> "Now the old people mostly complain that the government do not follow their words. They say one thing but do another." (Female, 75, Shiyoulu Community)

In having their voice heard, many felt that there was a stigma around ageing and older people, with their opinions and expertise being afforded lower priority than others in the smart city agenda. Participants reported a sense of helplessness, reflecting on their perceived lack of value to the local community, and a feeling of marginalisation:

> Interviewer: "What do you think is the best way for older people to improve the current problems?"
>
> Participant: "Nothing needed. An old person can do nothing. Others dislike older people." (Female, 83, Hualongqiao Community)

"It is nonsense to participate in the local development, because nobody wants to hear our voice. Nobody really cares what we say whenever we give suggestions and comments on developments such as the smart city. We've been marginalised. Who cares about you? No one care about you." (Male, 67, Shiyoulu Community)

Participants emphasised the value of participation in the community in terms of being informed and aware about what is happening. In the types of participation which could be better supported through the smart city agenda, older adults specified both online and offline. For those experiencing mobility challenges, then online participation provided an opportunity to participate, providing they had the technology and means to do so. For others, collective participation through in-person and face to face engagement was important. In all cases, engagement and participation in the smart city agenda were seen as integral to feeling a sense of purpose and citizenship in society:

"So participating in making smart city policies or getting involved with the society should be accessible from both online and offline." (Female, 87, Dahuanglu Community)

"I think so. It can broaden our views. It would be convenient. And we can have a better involvement with society, which is also a kind of way to participate in society." (Male, 84, Hualongqiao Community)

In addition to having the opportunity for older people to participate in the planning process, many reported on the need to ensure that the experiences of older people are incorporated into the smart city agenda. By involving multi-agency groups and engaging rights and advocacy organisations in the smart city agenda, then the rights and interests of older people can be increasingly protected. To others, the role of older people as community leaders was central to developing smart city interventions that reflected the requirements of older people. An enhanced role for older people's champions as advocates for change was important in delivering meaningful interventions:

"Then we need the community leaders to manage the community well. They can lead us and guide us. If they do not manage the community, then no matter what things we do is meaningless." (Male, 67, Shiyoulu Community)

For others, participation in the smart city agenda was closely related to the quality of engagement with services. Although older people felt that accessing services and information online was important, smart technologies cannot replace manual and face-to-face service delivery. The importance of "local navigators" was crucial here, having offline services and guidelines available in the local community, advising people through the technologies and services to facilitate access for older people:

"Those digital services are good, I know. But the problem is that we don't know how to use it. For example, if you want to take a taxi outside, you have to book it online, because there are many internet cars now, we, older people don't know how to take that digital taxi. So we don't even take a taxi because we don't know how to use that app and there's no one to teach us, no one to guide us. For example, if you don't know how to use it, it would be helpful if the community or the platform could have someone around to teach you how to use the application and guide you when we are using these services. Without someone to teach us, we don't know how to use them, and we won't use it." (Female, 76, Dahuanglu Community)

Perceptions of participation and engagement raise critical questions for the smart city and ageing agenda. A lack of opportunities to participate in smart city development could potentially exclude older adults from the decision-making process resulting in disengagement and disillusionment with smart cities. In our participant accounts, this was linked to feelings of disempowerment and disenfranchisement, as well as undermining their sense of citizenship in the smart city. Building trust and reciprocity among government, service providers and older people is an essential step toward developing inclusive smart age-friendly cities. Different forms of participation are needed to reflect the desire and ability of older people to participate in different ways. Likewise, the voice of older people needs to be shared and heard in a more meaningful way, prioritising their experiences of living in communities.

DISCUSSION

In this study, we sought to explore experiences of older people living in a smart city and discuss how social inclusion amongst older people can be supported in relation to technology development and smart city interventions. Through the five key themes presented in this paper, we have explored the role of smart city development in the lives of older people and its ability to support the ageing in place requirements of older people. Our findings revealed there is the potential for technology and smart city interventions to address some of challenges of an ageing society (23). For example, in maintaining and supporting strong familial connexions while strengthening the social participation of older adults. Likewise, smart cities can potentially provide opportunities to access health information online to enhance self-health management and well-being. Yet smart cities also bring about challenges that need to be overcome in order to support the inequities of ageing across urban environments. In some cases, the smart city agenda and digitization more broadly has the potential to reinforce urban inequalities, through inconsistencies in access to technology, thereby creating a digital divide and enhancing social exclusion (58). There was a deep misunderstanding and mistrust amongst older people regarding the use of the smart city and its aim e.g., surveillance. Furthermore, many feel excluded from the smart city agenda, excluded from urban place-making practises and the development and deployment of smart city technologies. In order to deliver smart, "inclusive" environment for older people, active participation and empowerment of older people should be considered as a priority in smart city development. In doing so, this discussion points toward some specific recommendations for ageing and smart city theory, policy, and practise moving forward, if it is to deliver socially equitable and age-friendly outcomes for older people. We bring together the findings from the research with the burgeoning literature on age-friendly cities and communities to identify potential ways forward.

Theories of Ageing, Place, and Technology

Theories of environmental gerontology have explored older adults relationship with their environment, building on notions of person-environment fit to explore the extent to which everyday settings e.g., home and community, support changing contexts in old age (95). More recently, this has included an appreciation of the relational, interconnected, and interdependent ways in which older people form attachments with their immediate environment (47, 96). At the same time, critical gerontology has identified the disconnect between technological interventions and ageing-in-place, citing that technological supports often lack the ability to deliver on forms of social participation and community integration which are integral to ageing-in-place (97). Going forward, further transdisciplinary work is needed to bridge theories of gerontology with smart city discourse, to explore how we can better integrate notions of ageing-in-place in smart cities. If we are to deliver smart urban environments that support older people, then we need to ensure that such technology is able to build relational aspects of place in the lives of older adults, where smart city interventions enable social participation, community participation and civic engagement. Likewise, there is a need to learn from smart city theory to examine how we can address issues of surveillance, empowerment, and rights to the city in the context of age-friendly environments. For example, theories of smart citizenship (98) offer valuable theoretical frameworks for conceptualising issues of power in the context of the smart city and emphasise the need to challenge top-down models of smart cities. This is important if we are to support a rights and citizenship agenda, where older people are central to driving forward smart city interventions.

Integrated Smart City-Age-Friendly Policy Discourse

Whilst social inclusion was considered important in supporting health and quality of life for older people, and many could see the potential for technological supports to enable ageing in place, there is no existing interconnected policy framework for ageing and smart city policies in China. Given the expansion of the smart city movement and the rapidly ageing society in China, closer integration of these agendas is important to realise the potential of smart urban environments in supporting positive outcomes in old age. Age-friendly interventions already offer a potential framework through which to connect the vision of ageing and social inclusion, of which smart cities and technology should be a cross-cutting strand. Important here, is realising and joining up the smart city agenda with each of the various dimensions identified in the WHO (27) age-friendly framework: (1) Outdoor spaces and buildings; (2) Transportation; (3) Housing; (4) Social participation; (5) Respect and social inclusion; (6) Civic participation and employment; (7) Communication and information; and (8) Community support and health services, so that there is a cross-cutting and holistic approach to bringing about change. This requires more integrated and joined-up solutions (41) that establish how smart cities can "speak to" and address some of the key challenges of an ageing population, e.g., housing, outdoor spaces, health and well-being, participation and engagement. Failing to deliver integrated solutions, will likely continue to see smart cities and ageing as separate strands of urban and social policy, creating silos and disconnected practise, which will fail to deliver the wraparound digital supports that older people need.

Ageing, Social Inclusion, and Connected Communities

Participants identified what they wanted from smart city technologies in terms of enhancing their social participation and inclusion, highlighting the importance of residing in connected communities when ageing in place. This involved three specific domains and criteria for the smart city in terms of enabling physical, social, and community connectivity. These were integral to personal development, maintaining interdependent relationships in old age, and supporting well-being and quality of life. Physical connectivity related to the direct engagement with services and service providers, enabling people to access services as and when they need them. Social connectivity related to how smart technology can facilitate social relations between family and friends, as well as informal social support networks to support everyday health and well-being. Community connectivity relates to the wider engagement of older people with the community, in terms of opportunities for participation and meeting others, i.e., involvement in community life. These three domains represent important areas of priority for smart cities, in terms of delivering on socially inclusive age-friendly communities for older people which support relational connections in old age and create truly interconnected and interdependent communities.

Inclusive Smart Cities and Widening Participation

Whilst ICT-based technology had the potential to bring benefits to older people's everyday life, there were a number of challenges to using digital technologies. These concerned: (i) financial constraints, (ii) digital literacy, and (iii) health and cognitive issues in old age which prevented older groups from being able to access digital supports. These exclusionary barriers have the potential to widen social inequalities and undermine the social inclusion agenda, compounding isolation and exclusion for the more "hard to reach" older adults. These issues have also been supported by Fang et al. (58) and Lee et al. (99) in the literature. As technology is becoming a more pervasive part of the urban environment, then services and supports are becoming increasingly digitally mainstreamed. Our participants highlighted serious concerns and anxieties regarding access to digital services. For those that are digitally connected, then realising those opportunities for active and healthy ageing will become more feasible in the context of a smart city. Educating older people to improve their digital literacy can potentially improve mental and social well-being (99). In contrast, for those who are digitally excluded, there is the danger that the inability to access supports will open up new health and well-being inequalities. Smart cities need to ensure that technologies are accessible for all, are inclusive (regardless of financial means) and that digital literacy becomes a central component of delivering interventions. Moreover, technological change can be overwhelming for older people, in the same way that housing transitions and other sudden societal changes can lead to negative

outcomes in old age. Managing digital change and transitioning it effectively in the lives of older people is important if we are to realise the benefits of smart technologies.

Rights, Ageing, and the Smart City

In delivery of smart cities, two critical issues were raised in the context of rights and the digital city. In terms of governance of smart city initiatives, many were concerned about the ubiquitous use of technologies in monitoring the public and private life of older people. Participants expressed concerns over what data was being collected, how that data was being used and who controls and owns that data (83). This is perhaps more pertinent given the case study context and the increasing surveillance in China which has been well-documented (85). As smart cities have the potential to establish varied and complex digital connections across the city, there are concerns over its intrusion into private life. Here, the smart city agenda needs to ensure that autonomy, choice, and control are supported (81), involving older people in decision-making about how data is being managed and utilised. Too often, people are presented with a "privacy trade off" in being promised more efficient services, yet in supporting the health and well-being of older people, there should be clear transparency over monitoring technologies and the data that is being monitored. A related point here is the danger of creeping privatisation and commodification of services as part of the smart city (8), which many of our participants were concerned would lead to the exploitation of older people. The smart city agenda needs to ensure that the notion of rights is reconfigured in the context of smart technology, ensuring that the rights of older people to age in place are forefronted (e.g., right to move around urban spaces, right to safe and secure housing, right to employment opportunities), whilst balancing a set of rights in the context of technology and data monitoring e.g., the right to privacy, security, and safety. In configuring these rights, there needs to be a central role for older people's advocacy groups, NGOs and community stakeholders, alongside the public and private sector, in multi-agency partnerships built upon good governance and ethics, which ensures a rights based approach to the provision of supports for older people in the context of the smart city.

Co-producing Smart Age-Friendly Cities

Our findings pointed to a lack of information and knowledge amongst older people about the notion of the smart city and technologies associated with it. For many, smart cities were seen as empty policy rhetoric. This suggests that significant work needs to be undertaken around the smart city agenda to engage older people. Much smart city research has criticised its implementation in terms of top-down approaches to technological implementation. This has had the impact of alienating older people who do not talk "the policy language" from engagement in constructing what smart cities are and was deeply disempowering for our participants. As a result, thus far smart city policy has little relevance to older people and the practise responses have failed to address their everyday lives. Smart cities need to ensure that older people are (i) informed and realise the benefits of smart city interventions and (ii) are actively involved as partners in the design and deployment of the smart city agenda. Producing digital products that are responsive to the needs of the users will not only increase the acceptance of older people in a technology-led society, but will also bring positive outcomes for older people as technology is shaped around the lives of older people. There is much we can learn from the age-friendly city and community movement here regarding wider citizenship in the context of the smart city. For example, age-friendly champions and older people's forums have been fundamental in delivering on the citizenship aspect of the age-friendly agenda, where older people are at the centre of policy-making decisions. Similar empowering practises are needed to ensure that the voice of older people is used in a positive way to drive a smart, age-friendly agenda.

CONCLUSION

This research adopted a qualitative case study approach to investigate the experience of older people living in a smart city in China, and to discuss how technological initiatives and smart city interventions can support the social inclusion of older people. Our findings revealed the opportunities and challenges of supporting social inclusion amongst older people living in a smart city. In the research, we specifically focused on the lived experience of older people across three communities in a smart city in Chongqing, China. In terms of opportunities, interconnected smart technologies at a city scale, can deliver potential positive health and well-being outcomes, and our participants were optimistic about the role of smart cities in supporting age-friendly urban environments through deeper physical, social, and community connectivity. Yet, there exist a number of challenges to delivering improved social outcomes for older people, including how smart technologies can deliver improved autonomy, choice and control, as well as ensuring that smart interventions are equitably delivered including the need to: enhance social participation and social supports for all; supporting role fulfilment and changing identities in old age; and encouraging interdependence among older adults. Lastly, closer reconciling of the age-friendly agenda with smart city policy and practise is needed to ensure changes at the city level deliver promised well-being and quality of life benefits in old age. This is critical if smart cities are to respond to ageing societies and realise their potential role in delivering positive social outcomes for older people.

Limitations and Implications for Future Research

We conclude by highlighting some strengths and limitations of the work. This works draws upon experiential case study research in specific communities in Chongqing, providing insight into perceptions of smart cities and ageing-in-place amongst older people. Whilst this has addressed an important gap, more research is needed to explore perspectives across different smart city case study locations in China and globally (including the Global South) and their impacts on the ageing population. This would enable us to build up a more comprehensive understandings of smart city impacts across different city planning and governance frameworks. In terms of sampling, we do draw upon a diverse range of experiences by age, gender, and place, but it was outside the scope of this study

to undertake an analysis of that data by specific age cohorts, although we recognise this is needed in order to capture the diverse experiences of different age groups in relation to age-friendly cities and attitudes to technology and smart cities which are known to differ by age (young-old; old; and the old-old). Likewise, the sample did not fully capture older people across various categories e.g., cognitive decline, although there is reason for us to believe that this impacts on technology use and the types of age-friendly interventions required at a community and city level to support ageing in place. Lastly, in collecting the data as part of this study, it was complex for older people to visualise the notion of the smart city. Prompts were often needed in focus groups, such as examples of smart city initiatives, to elicit discussion. This speaks to the need for closer involvement of older people in the smart city agenda, through city initiatives which directly engage older people to ensure they are more informed and aware of what constitutes the smart city, but which nevertheless also speaks to a weakness in the data collected.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Heriot-Watt University's School of Energy, Geoscience, Infrastructure and Society Research Ethics Committee. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

ML and RW: conceptualisation and methodology. ML: investigation, data collection and analysis, writing—original draught preparation, and visualisation. RW: review, editing, and supervision. Both authors have made significant, direct and intellectual contributions to the work, and approved the submitted version for publication.

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21st Century Good Neighbor Program: An Easily Generalizable Program to Reduce Social Isolation in Older Adults

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Aim: In this once-in-a-lifetime humanitarian crisis, what does it mean to be a good neighbor? It means that as a community, we must address loneliness and barriers to care faced by vulnerable populations such as older adults. We share an inexpensive longitudinal experiential service-learning program implemented by health professions and undergraduate student volunteers that aims to help alleviate loneliness in older adults while imparting meaningful experiences to volunteers.

Intervention Design and Setting: The 21st Century Good Neighbor Program is an observational cohort study of an experiential service-learning program started in May 2020, and this article shares the results collected after 1 year. This longitudinal, weekly phone call program was conducted in a single community setting in the Midwestern part of the United States. Older adults over the age of 60 served by a local community service agency (CSA) were invited to participate. Volunteers consisted of students 18 or older. Student volunteers made regular phone calls to a pair of older adults throughout the course of 1 year following standardized call scripts. The loneliness of the older adults was measured by volunteers using the 3-item UCLA Loneliness Assessment.

Results: 261 older adults were engaged in conversations with a volunteer. A total of 1,391 calls were accepted by older adults and the median length of a welcomed call was 11 min. The average baseline loneliness score was 4.156 ± 1.41 and the prevalence of social isolation was 19.5%. There was no significant change in the UCLA loneliness score in the first year of follow up. However, a majority of volunteers (88%) agreed or strongly agreed that the program had a positive impact on them. In addition, the program identified 257 issues older adults faced that required follow-up. The most prevalent concerns referred to the community service agency by volunteers were issues related to utilities, food and transportation access.

Conclusion: The 21st Century Good Neighbor Program is a unique intervention in which student volunteers and older adults paired by a community service agency forge relationships though a longitudinal phone call-based program. This easy-to-implement

program provides another layer of support to identify and refer issues that impact social determinants of health. The added benefit of volunteer satisfaction in the setting of COVID 19 pandemic is heartening. We hope to continue to study the impact of this intervention on social isolation in this vulnerable population.

Keywords: social isolation, telecommunication, neighbor, student volunteers, social determinants of health, scalable program, loneliness, older adults

INTRODUCTION

With the rise of the COVID-19 pandemic, social isolation has grown rapidly throughout the country (1). A particularly vulnerable demographic, those above the age of 50, have historically had the largest rates of social isolation before this pandemic (2). Social isolation can be determined by the size of the network a person possesses, as well as the frequency with which a person engages meaningfully with individuals in their network (3). Loneliness, a variable defined as the discrepancy between an individual's perceived social connections and desired social connections, is also frequently discussed in relation to social isolation (3, 4). Both are found to be dependent on geographic location, gender, age, and income (5–7).

Loneliness and social isolation are affected by neighborhood factors. One convergent mixed-methods study showed that adults who lived in more densely populated areas of a city experienced significantly less loneliness and social isolation, and a sense of community even when variables such as gender, socioeconomic status, and ethnicity were controlled for (6). It is also well-known that loneliness and social isolation can impact health. Loneliness has been associated with a higher risk for developing dementia, less physical activity, depressive symptoms, undernutrition, lack of life satisfaction, and higher risk of mortality (8–11).

This pandemic has been unprecedented in both the duration and magnitude of physical distancing measures implemented by the federal government, leaving many cut off from physical and beneficial social connections. The COVID-19 pandemic has exacerbated many deleterious effects linked to loneliness and social isolation—such as anxiety and depression—in many age groups (12, 13). Recent studies suggest that older adult groups are particularly susceptible to being adversely affected by the COVID-19 pandemic and have one of the highest risks of any age group for developing clinical depression, anxiety, and other disorders from social isolation (2, 3, 14, 15). It follows then that addressing loneliness and social isolation plays a vital role in ensuring the health of individuals, making it a key target for intervention, especially during the ongoing COVID-19 pandemic. This is true for students and young adults as well, although the impact is not as dramatic.

A literature search in the field of social gerontology reveals multiple ways in which older adults experience social connections. The framework characterizing the experience of social experiences in later life includes three areas: personal relationships, community connections, and social engagement (16). Studies suggest that preventive social services should target new contacts in developing opportunities for socialization among older adults through a framework called MODEL (Model of Depression and Loneliness). A systematic review on interventions targeting loneliness and social isolation among older adults suggests that new technologies and community-engaged arts are promising tools to combat the same (17).

In this descriptive study, we evaluate the longitudinal effects of using simple technology like telephone calls to foster social engagement and potentially reduce the social isolation among older adults (18–20). The 21st Century Good Neighbor Program is centered around student volunteers from a public university (University of Illinois Chicago) making phone calls to older adults who are served by a community services agency in IL. Calls made to older adults by student volunteers are outlined by standardized call scripts. The ongoing partnership with the community service agency helps provide a method to quickly address any issues reported by older adults. This phone-based intervention creates virtual spaces for meaningful longitudinal engagement of student volunteers with a "neighbor" providing much needed social connections during, and potentially after, the COVID-19 pandemic.

MATERIALS AND METHODS

Recruitment of Participants

Older adults aged 60 years and over living within the 8 counties served by the community service agency (CSA) were invited to participate in this program. This was done by mailing a postcard informing them of the 21st Century Good Neighbor Program.

Students aged 18 years and older were invited to participate as volunteers in this service-learning program. These volunteers were recruited through multiple means including emails and student organizations in the colleges of pharmacy, medicine, engineering, liberal arts and sciences, applied health sciences, and public health.

Intervention

The community service agency (CSA) paired student volunteers with their older adult clients in the community. During the first call, if the older adult consented to participate in the program, a trained volunteer continued the phone call using the program's standardized phone scripts (**Supplementary Material**).

Phone Call Scripts

These scripts were created by student and faculty leaders at the inception of the program and provided electronically for student volunteers to fill out (provided in **Supplementary Material**). The scripts contain both explicit questions volunteers need to answer and provided tips for engaging in active conversations.

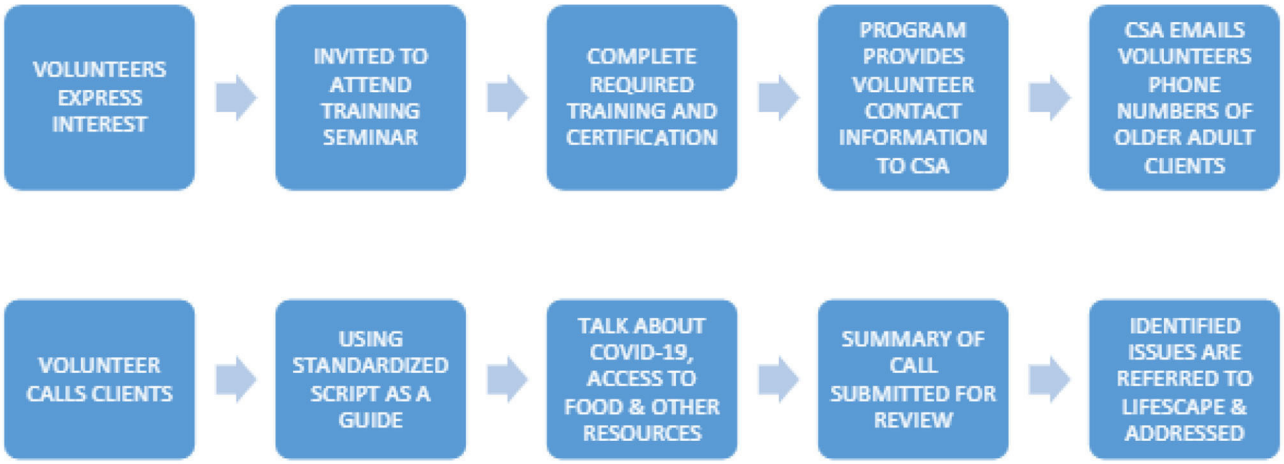

FIGURE 1 | Flowchart outlining 21st Century Good Neighbor Program's intervention structure, steps taken by volunteers to engage in meaningful social interaction with older adults, and the methodology for collecting information.

The 1st phone script served as an introductory conversational call about health and well-being, provided health information on COVID-19, and assisted participants in accessing resources such as meals and utility support. A copy of the call scripts can be found within the **Supplementary Material**.

The 2nd phone call script (used for calls conducted a week later), prompted the volunteer to enquire about the health of the older adult and complete an assessment on loneliness using the brief UCLA Loneliness Scale (21). A score of 5 or above on this scale suggests that the adult is experiencing social isolation. Volunteers were instructed to utilize the UCLA Loneliness Scale on the 2nd phone call because loneliness is a sensitive topic; volunteers used the first phone call to instead build a sense of trust with their older adult client.

The 3rd phone call script prompted the volunteer to assess the need for health and wellness services and other senior-related assistance programs available through the community service agency. The final scripted phone call continued to provide an opportunity for the established relationship to grow, and to help volunteers gain confidence in engaging conversation with older adults and learning from the older adults' experience about some social determinants of health.

After the third phone call no more scripts were used. However, students were prompted after each phone call, any identified social issues and client needs were documented by the volunteer and referred to the CSA to be addressed. A summary of this intervention procedure is captured below in **Figure 1**.

This program fostered partnerships between student volunteers and the CSA by identifying problems that clients have, and a pathway for follow-up on the identified problems. It also fostered a mutually beneficial longitudinal relationship between the volunteers and older adults.

Statistical Analysis

An exemption waiver for IRB approval was granted by the UIC Rockford IRB to analyze the data obtained from the calls. The IRB approval number is 1713652-2. Descriptive statistics (e.g., frequencies, mean and standard deviation), were used to describe the demographics. Results are presented as mean ± standard deviation (SD) or as frequencies and percentages. The median with the interquartile range (IQR) were used to describe non-parametric data. An alpha of <0.05 was set as a level of statistical significance. All data analysis was conducted on Python 3.8.

RESULTS

1361 older adults were assigned to volunteers. 62% of the population identified themselves as female. 28% of the adults identified themselves as Black. 5% identified as Hispanic and the rest identified as White. The majority of the older adults, specifically 920 (67%), fell into the low-income category. 817 or 60% of these older adults lived by themselves, while 24% lived with one other person. Three percent of the older adults contacted were veterans.

Four hundred and eighty volunteers were in the inception cohort. Forty percent of the volunteers were undergraduate students at UIC, with the remaining volunteers attending various graduate programs at UIC–most commonly the Schools of Medicine, Pharmacy and Public Health at UIC. Approximately 276 (50%) of the initial enlisted volunteers were undergraduates, 88 (20%) were medical students, 57 (14%) were pharmacy students, and 59 (14%) were public health students.

A total of 1,391 calls were welcomed and the median length of a welcomed call was 11 min IQR (18). The descriptive statistics for the duration of calls by call number is provided in **Figure 2**.

UCLA Loneliness Assessment of Older Adults

The UCLA Loneliness assessments were initially assessed in 141 older adults, and the average baseline score was 4.156 ± 1.41. The initial score of the 84 adults who completed at least one follow-up UCLA questionnaire was 4.15 ± 1.41. This was similar to the score of 4.16 ± 1.00 for the 57 adults who did not complete the follow-up UCLA questionnaire. No significant relationship was

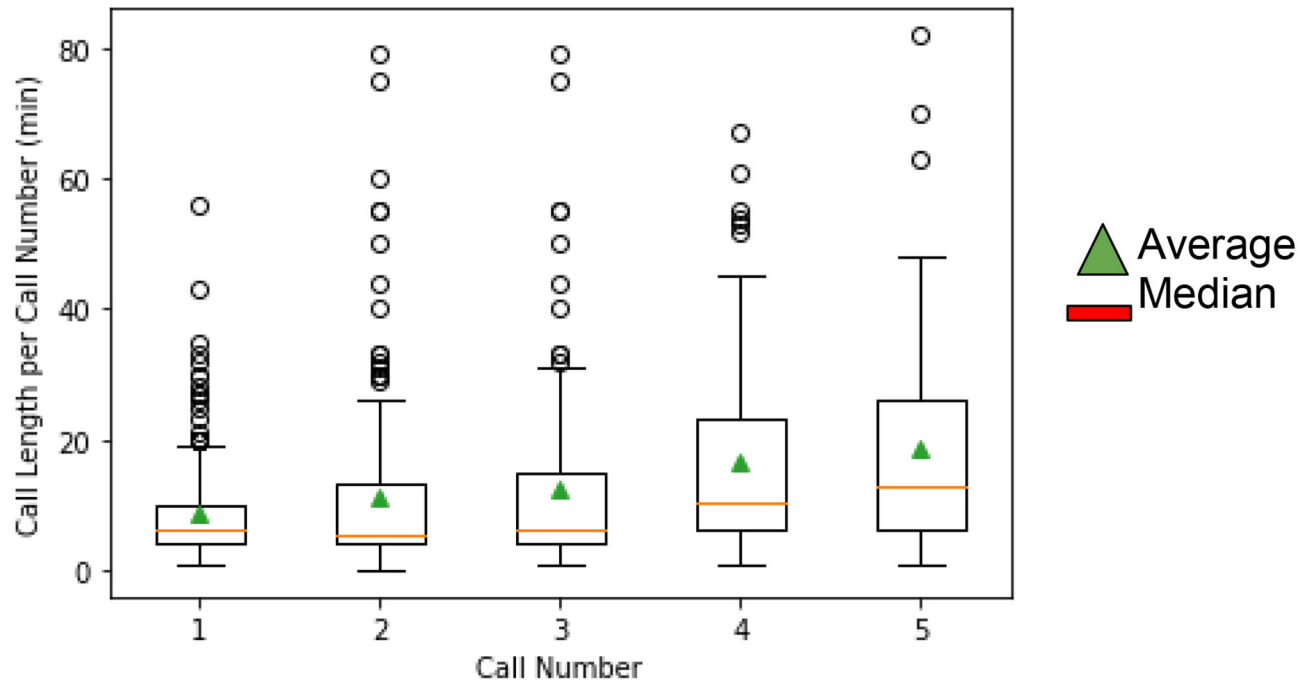

FIGURE 2 | Call duration per call number. This figure depicts the descriptive statistics for the length of call in minutes per call number.

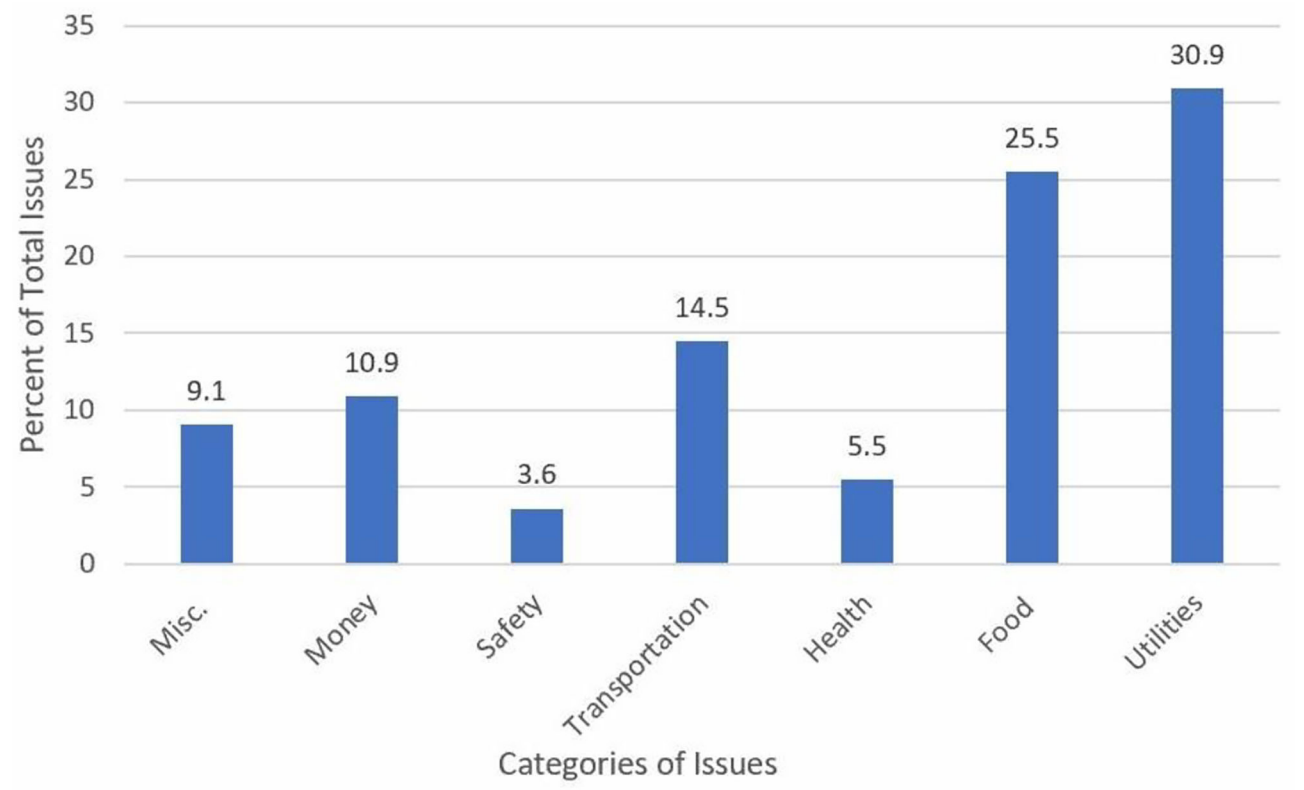

FIGURE 3 | Categories of client issues that were referred for follow up.

found between the change in UCLA Loneliness Assessment score and either the duration or number of calls.

Client Issues Requiring Follow Up

Volunteers identified 257 issues requiring follow-up as a result of these calls. Of these, detailed information was provided for 132 issues. Access to necessities like food and utilities accounted for over 50% of these issues, followed by monetary issues and lack of access to transportation (see **Figure 3**).

Volunteer Satisfaction

The impact of each call on the volunteer's life was measured based on responses to the statement "The call led to a renewed sense of meaning and purpose in my life." The students were asked to rate their agreement with this statement on a five-point Likert scale: 1 (strongly disagree), 2 (disagree) 3 (neutral), 4 (agree), 5 (strongly agree). As shown in **Figure 4**, 88% of volunteers agreed with the aforementioned statement.

DISCUSSION

The purpose of this service-learning program was to mitigate the deleterious effects loneliness may have on community dwelling older adults by building lasting and meaningful social relationships with student volunteers. This intervention is novel in that it provided the opportunity for a longitudinal relationship between the volunteer and older adult. The collaboration with the aging agency helped address issues related to social determinants of health that affected older adults during the pandemic.

There has been an explosion of research showing the harm of social isolation to populations at-risk for depression, suicidal thoughts, or other indicators of an unhealthy mental or physical state (2). In light of these pressures, no change in loneliness score is important. Among older adults with no change in loneliness score, we noticed a trend towards significance in the relationship between increasing duration of calls and UCLA loneliness score. We will follow up to determine whether the investment of more time in fostering the relationship will help to combat this loneliness epidemic (see **Figure 2**).

Few studies have investigated the benefit volunteers gain from a meaningful relationship with older adults. In the setting of the pandemic, it is exciting to see the benefit volunteers experience from participation in this program.

One of the limitations of this study is that only 141 of all 261 adults completed the first UCLA questionnaire. Of the 141, only 84 completed the second UCLA questionnaire with an attrition rate of 40%. However, the program is ongoing and we hope to complete the remaining questionnaires.

As de-identified data was used, we could not account for missing data. To account for non-response bias, we compared the initial loneliness scores for the group that completed one

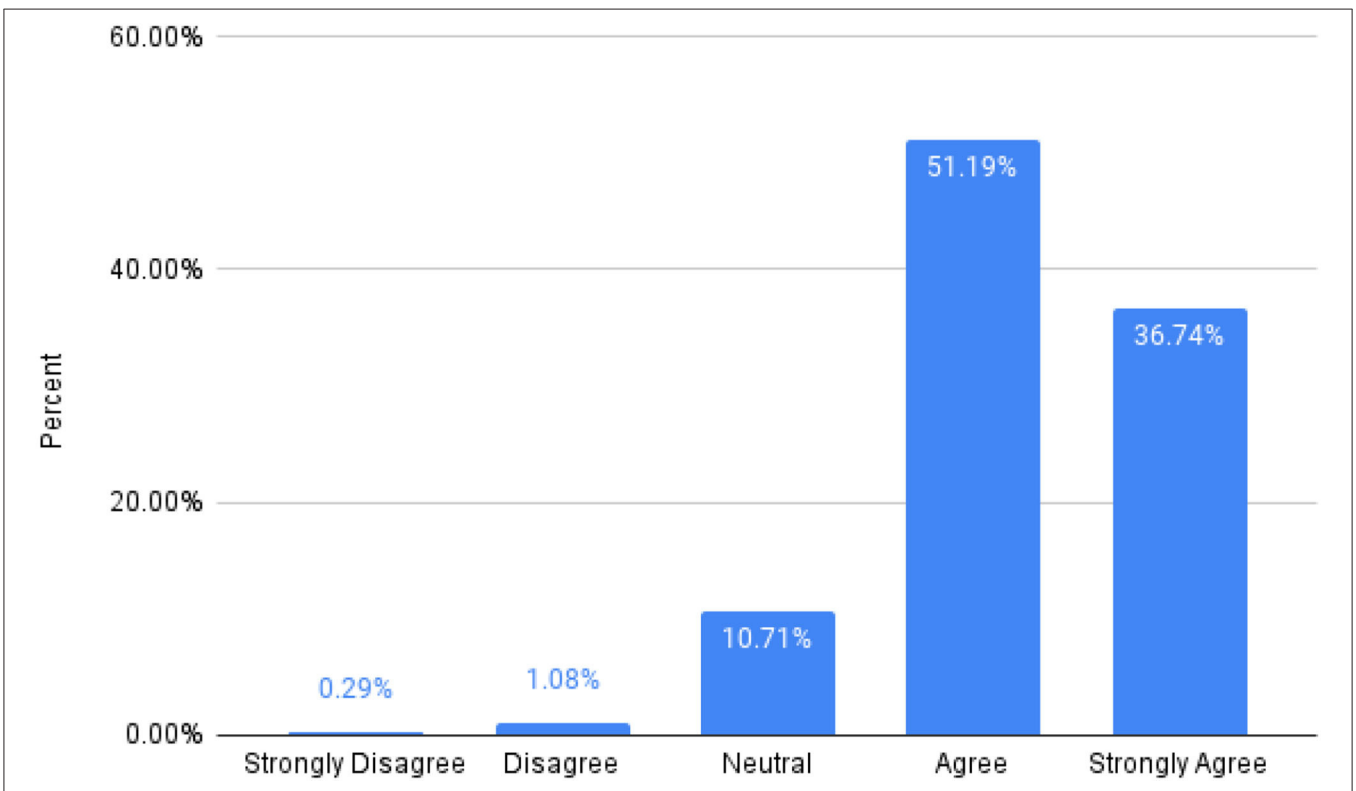

FIGURE 4 | Percentage distribution of satisfaction scores in volunteers. This chart depicts the percentage of volunteers who agree that the program has made a significant impact on their life (administered through a volunteer satisfaction survey). Nearly 88% of the calls were reported to have a positive and meaningful impact on the volunteer's life, with <2% of calls resulting in a disagreement with the statement presented.

questionnaire to that of the group who completed multiple questionnaires. The loneliness scores were similar.

Given that older adults participating in this program were already enrolled with a community service agency, they may already have been in need of aid, so it is likely that the data cannot be generalized to the population at large.

One randomized controlled trial of peer support using home visits and telephone calls, showed a statistically significant decrease in loneliness and increased resilience among older Chinese immigrants in Canada (22). Yet another program in Japan showed that interventions aimed at preventing social isolation in older adults were effective when they utilize existing community resources (23). The 21 Century Good Neighbor program is similar to these studies in that it is a volunteer-based phone call program using existing community resources by partnering with a community services agency.

In contrast to similar studies within the United States, volunteers in the program underwent mandatory training to actively engage in meaningful social interactions with older adults, referring older adults to the Community Service Agency, and reporting elder abuse (24). Our program is unique in that it is longitudinal; the same student continues to talk to the older adult on and off for a year, building valuable rapport.

When assessing volunteer satisfaction with the program, we used a single question (see **Figure 4** legend) to ensure that our volunteers reflected on the benefit of their interactions with each call. Despite the social desirability bias that may come with this method of assessing satisfaction, this threat is inevitable in any intervention with a similar humanistic goal that assesses "satisfaction" among its volunteers or employees. To assess volunteer satisfaction, we used a short question, rather than a long, validated questionnaire. We felt that this would easily capture the desired information and also identify if volunteers experienced burnout.

We expect that using volunteers leads to selection bias, which exists for any similar intervention where the goal is to help another person. We see this "bias" as a strength of our volunteer-based intervention. Selection bias is also an issue as the older adults who agree to participate in the intervention may be different from the rest of the population.

In a time as challenging as this pandemic, obtaining real-time information on the well-being of the older adults is necessary and important. For instance, almost half the older adult clients reported lacking basic necessities for survival, such as insufficient food, water, electricity, etc. This program offers a novel method through which we can address in real-time problems older adults may be facing. The fact that these issues were unaddressed until adults brought them up to the student volunteers is of much concern. Many other older adults may silently be suffering from these issues and may not have family or friends to turn to.

We recognize that many of these results can also be due to confounding variables. We plan to explore the effects of gender, age, socioeconomic status, ethnicity, and income on loneliness and social isolation in the future.

The central focus of this paper is to outline the program's structure and its potential to cultivate relationships between volunteers and older adults. One limitation is that each volunteer older adult pair is unique and that results may not be very easily generalized. However, we have shared this approach with sister institutions in the Midwest and have been able to successfully implement similar programs. The generalizability of the data to beyond the Midwest and to non-English speaking cohorts of older adults is to be determined.

This paper provides the framework for this initiative, with the hope that institutions of higher learning can spearhead this in their own communities. This would provide a broad base for further evaluation of the effects of using simple measures like phone calls on limiting loneliness in the older adult populations throughout the country.

As the pandemic subsides in the future, further examination can be conducted using a hybrid approach of both telecommunication and in-person visits on loneliness levels of adults. Building meaningful social relationships, engaging in conversation about new topics, and maintaining mental health in older adults must be approached with an open mindset and multidisciplinary approach. This entails innovating resource-efficient interventions that are accessible to older adults and utilizing volunteers ready to learn how to actively engage with older adults and help; this program represents a step forward in protecting mental health during the 2020 COVID-19 pandemic (25–27).

In conclusion, the 21st Century Neighbor Good Neighbor program was established to fight the rise of loneliness during the COVID-19 pandemic. Through a volunteer base that made phone calls to their assigned older adults, a longitudinal connection was formed that expanded the social networks of elderly individuals in Illinois. A positive effect of the program was seen among volunteers as most calls led to a renewed meaning and purpose in the lives of volunteers.

This program is by no means a causal remedy for loneliness or depression. After all, no one program is. One of the most outstanding aspects of this program, in addition to its longitudinal nature, is its easily implementable and scalable structure that shows promising results for reducing loneliness of older adults. The investment needed is minimal and it can be easily adopted by other universities. In turn, this can lead to not only less lonely older adults, but also unprecedented levels of student engagement and responsibility. This reasoning lends itself to the potential ubiquity and demonstrated utility of this program; it follows that from the observed results, similarly implemented and organized programs in other undergraduate and graduate institutions could lead to a remarkable change in loneliness experienced by older adults and increased sense of self-worth in student volunteers. This may allow for the development of more creative, efficient multidisciplinary solutions to help improve the quality of older adults' lives (10).

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by IRB Administrative Body–(Exempt). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

SSr and SSa designed and conducted the statistical tests used on Python. ACr helped construct the call scripts necessary for data collection. SSr, SSa, LCo, and ACr were involved in writing the manuscript. LCh, RS, and HO oversaw the progress of the manuscript and created the 21st Century Good Neighbor program, KG oversaw the data analysis and ACa provided part of the demographic data used. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.766706/full#supplementary-material

Supplementary Material | The four call scripts used in this intervention.

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An Integrative Framework to Guide Social Engagement Interventions and Technology Design for Persons With Mild Cognitive Impairment

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Social isolation and loneliness in older adults are associated with poor health outcomes and have been linked to an increased risk of cognitive impairment and incident dementia. Social engagement has been identified as a key factor in promoting positive health behaviors and quality of life and preventing social isolation and loneliness. Studies involving cognitively healthy older adults have shown the protective effects of both in-person and technology-based social engagement. However, the benefits of social engagement for people who are already at-risk of developing dementia, namely those with mild cognitive impairment (MCI), have yet to be elucidated. We present a narrative review of the literature, summarizing the research on social engagement in MCI. First, we identified social networks (quality, size, frequency, and closeness) and social activities (frequency, format, purpose, type, and content) as two overarching dimensions of an integrative framework for social engagement derived from literature examining typical cognitive aging. We then used this framework as a lens to examine studies of social engagement in MCI to explore (i) the relationship between in-person and technology-based social engagement and cognitive, emotional, and physical health, and (ii) interventions that target social engagement including technology-based approaches. Overall, we found that persons with MCI (PwMCI) may have different levels of social engagement than those experiencing typical cognitive aging. Moreover, in-person social engagement can have a positive impact on cognitive, emotional, and physical health for PwMCI. With respect to activity and network dimensions in our framework, we found that cognitive health has been more widely examined in PwMCI relative to physical and emotional health. Very few intervention studies have targeted social engagement, but both in-person and technology-based interventions appear to have promising health and well-being outcomes. Our multidimensional framework of social engagement provides guidance for research on characterizing the protective benefits of social engagement for PwMCI and informs the development of novel interventions including technology-based approaches.

Keywords: mild cognitive impairment, social engagement, social isolation, loneliness, technology, social activity, social network

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INTRODUCTION

Social isolation is the objective state of having few social ties or infrequent social interactions and is a critical public health issue that affects nearly a quarter of adults aged 65 years and older (1). Loneliness is the subjective experience of feeling isolated or not belonging and affects ∼43% of older adults (2). A growing body of evidence has linked social isolation and loneliness to significant health risks including increased mortality (3), morbidity (4, 5), and negative psychosocial outcomes (6–8). Moreover, factors linked to social isolation and loneliness in cognitively normal older adults, including small social networks, reduced participation in social activities, and poor social support, are associated with a 40–50% increased risk of developing dementia, even when physical activity, education, and depression are statistically controlled (9, 10). For populations who are already at a high risk of developing dementia, such as those with mild cognitive impairment (MCI), understanding the impact of social isolation and loneliness on disease progression and finding effective interventions is of particular importance.

MCI is an intermediate stage between normal aging and dementia, characterized by a modest decline in cognition that is greater than expected for an individual's age and education, but with relatively preserved ability to carry out daily living activities [e.g., eating, bathing; (11–13)]. MCI affects roughly 17% of people over age 60, with prevalence markedly increasing across the lifespan (14). Persons with MCI (PwMCI) are more likely to experience progressive cognitive decline compared to cognitively normal older adults, with an annual conversion rate to dementia of 10–15% (12, 15). This risk is compounded by the fact that PwMCI may experience social disengagement due to cognitive challenges making it more difficult to have fulfilling social interactions (16). Given the significant public health and economic impact of dementia with approximately 300 billion dollars spent on caring for persons with dementia in the US alone (17), addressing potentially modifiable risk factors such as social isolation and loneliness will be crucial to address this growing crisis.

Social engagement has been identified as a key target in addressing social isolation and loneliness and is defined as participation in social activities and maintenance of social connections with others (18, 19). There is a vast body of work examining the effects of increasing social engagement opportunities among cognitively normal older adults. These studies have found promising outcomes such as increased social support, higher levels of social activity, reduced feelings of loneliness, and improved psychological well-being associated with increased social engagement (20–24); for review see (25).

Additionally, there is evidence to suggest that social engagement may be protective against cognitive decline and incident dementia (18, 26–28) and may even lead to better cognitive functioning (29) and increased cognitive reserve (30, 31). The majority of these studies have examined in-person opportunities for social engagement; however, advances in technology with more affordable options becoming available have provided new ways for individuals to engage socially with others from the comfort of their own homes, and have served as a lifeline during the COVID-19 pandemic (32, 33). Studies conducted pre-pandemic showed that technologies such as videoconferencing, social networking, and social robots had the potential to increase social engagement among older adults [for reviews see (34–36)], a matter that has become increasingly important in light of the recent pandemic.

Although the cognitive aging literature generally supports the role of social engagement as a protective health factor and shows promise for social engagement interventions, the benefits of in-person and technology-based social engagement for PwMCI are not well established. Thus, the goal of this narrative review was to summarize the research on social engagement in MCI, in particular the relationship between social engagement and various health factors and the efficacy of social engagement interventions.

Social engagement is a multidimensional construct, with numerous components that could differentially relate to health. For example, one study using multiple measures of social engagement (social activity frequency, social network size, and social support) found that activity frequency and social support were more strongly associated with cognitive health than social network size, suggesting distinct mechanisms of action (29). Therefore, as part of this review, we first operationalized social engagement and its various components based on how it has been defined and measured in the literature among cognitively normal older adults. We then developed a framework of social engagement based on this body of published research to organize and guide our review. Using this framework, we examined studies of social engagement in PwMCI that fell into two broad categories: (i) studies exploring the relationships between social engagement and various health factors (cognitive, emotional, and physical); and (ii) intervention studies that have targeted social engagement.

GUIDING FRAMEWORK

Social engagement includes two broad dimensions: participation in social *activities* and maintaining a social *network*, or social connections (18, 19). In our social engagement framework (**Figure 1**), we represent *social activity* and *social network* as two related dimensions, each of which can be further characterized across various *structural* and *functional* components (37). Structural components relate to form or makeup of activities and networks (e.g., frequency) and are characterized by objective measures, whereas functional components relate to what these activities and networks provide an individual (e.g., quality) and are described by qualitative characteristics (1, 3). Our framework also represents the role of health and contextual factors guided by the International Classification of Functioning, Disability, and Health [ICF; (46)]. The dimensions and components are described below.

Activity

Social activity refers to participation in a task or event that involves some level of interaction with others and can be characterized by the structural components of

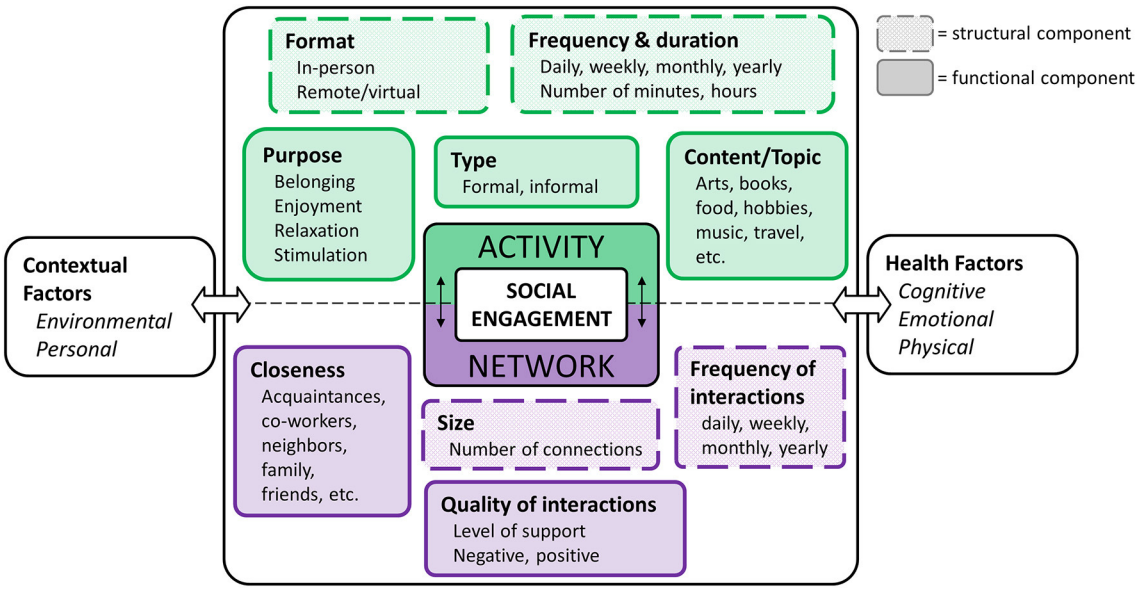

FIGURE 1 | Integrative social engagement framework.

frequency/duration and format, and the functional components of type, purpose, and content/topic.

The **frequency and duration** of social activity is typically measured across a range of different activities [e.g., going on a trip, going to restaurants, work, volunteering; (25)]. Such activities can occur in-person or in a virtual (i.e., technology-based) **format**. The degree to which an individual is engaged in a given activity often depends on the **type** of activity being performed. Activities that involve participation with an organized group or association can be described as formal (e.g., volunteer work, political organizations, religious groups), whereas informal activities tend to occur casually with others, for leisure [e.g., attending a concert, playing a game, visiting friends; (38–40)]. Similarly, older adults participate in activities for various reasons. For example, having a phone conversation with a friend, attending an exercise class, and volunteering at a local food bank are each likely to serve a different **purpose** and may relate to fulfillment of different social roles (41, 42). Activity **content/topic**, although not often addressed in the literature, characterizes the specific subject matter that is enjoyed or discussed during an activity.

Network

Social network refers to the relationships, or social connections, in a person's life (43). A person's network is characterized based on structural components of **size** (i.e., how many social connections a person has) and **frequency** (i.e., how often one interacts with any given social network member). Network is also described by the functional components of **closeness**, which refers to the proximity of social network members (e.g., family member, acquaintance), and the **quality** of those interactions (e.g., positive, negative). Importantly, the structural components of a person's network are often used to define the objective state of social isolation (1), whereas the functional components contribute to one's perception of social support. Having reliable, positive interactions contribute to overall well-being, but primarily negative interactions tend to increase stress and feelings of loneliness (44).

Contextual Factors

Contextual factors are known to impact a person's ability to remain socially engaged (45). According to the ICF, these contextual factors include both environmental and personal factors (46). **Environmental factors** typically refer to circumstances that are out of a person's control, or that occur externally to the individual. Such factors may include access to services and community (e.g., urban vs. rural), the infrastructure that exists in a given area (e.g., presence of community centers), how much social capital an individual has (e.g., economic status, inequity), and shared life events (e.g., hurricane, pandemic). On the other hand, **personal factors** typically refer to determinants that are internal to the individual, including age, race, gender, education level, coping style, etc. (46). Although not typically the focus of social engagement studies, these factors are often included as covariates in analyses.

Health Factors

Health factors can be subdivided into three general categories: cognitive, emotional, and physical. **Cognitive health** refers to a person's ability to think, learn, and remember, and is typically measured across a range of cognitive domains, including attention, language, memory, and executive functioning (e.g., reasoning, self-control). Distinct from cognitive health, **emotional health** refers to one's experience of emotional states and feelings (both positive and negative), interest in life, and life satisfaction that supports the subjective feeling of emotional

and psychological well-being. Poor emotional health may contribute to symptoms related to depression and anxiety (47, 48). Finally, **physical health** refers to the functioning of the body (internally and externally) such as mobility, sensory abilities, and vascular health.

Health factors may play a role both as an antecedent to and a consequence of social engagement, depending on the direction of the relationship. For example, a person experiencing cognitive challenges may experience a reduction in their level of social activity, where change in health is impacting the level of social engagement (49). Alternatively, those who do not participate in social activities may be at an increased risk of developing cognitive challenges, wherein health is impacted by the level of social engagement (8).

Overview of Review

The goal of this review was to characterize the relationship between social engagement and cognitive, emotional, and physical health for PwMCI, and to assess the existing evidence from interventions that targeted social engagement in this population. Our social engagement framework (**Figure 1**) was developed to guide the review by allowing us to (i) logically organize the results of our review, (ii) describe the factors that have been addressed in the literature, and (iii) identify gaps in the literature to inform future research. The findings of this review can be utilized to develop appropriate in-person and technology-based social engagement interventions for PwMCI.

METHOD

Article Identification and Selection

We conducted a search of the literature using Medline and PsycINFO, including peer-reviewed journal articles published between January 2000 and July 2021. We combined the search terms "mild cognitive impairment" AND "social ___ [engagement, connections, activity, network, support]." Article titles were initially screened for duplicates and relevance (e.g., review articles; non-MCI sample). We then reviewed the remaining full-text articles and only included articles that (i) included PwMCI at intake (or well-known alternatives such as cognitive impairment no dementia), and (ii) addressed at least one factor of social engagement from our framework (**Figure 1**). The first two authors (EL; LN) independently reviewed all full text articles identified by the search to determine whether they met the review criteria. Any discrepancies in their decisions were discussed by all the authors to reach a consensus. The selection of articles is illustrated in **Figure 2**.

Article Analysis and Coding

Articles were initially grouped into either cross-sectional and longitudinal observational studies or intervention studies corresponding to our two goals: (1) to investigate the relationships between social engagement and health factors (cognitive, emotional, physical); and (2) to review the evidence base for interventions targeting social engagement for PwMCI. For studies identified as relevant to our first goal, we listed out all of the measures used in each study. We then coded measures as either "social engagement," "health," or "other." Each social engagement measure was further coded to correspond to the factors in our multidimensional framework, and each health measure was coded as cognitive, emotional, or physical. Although our review focused on health factors, it is worth noting that many studies used contextual factors as covariates in their analyses, such as age, sex, location, etc., and often fell into the "other "category. Intervention studies were identified and categorized based on if the intervention approach was in-person or technology-based.

RESULTS

We address our first goal by presenting findings from cross-sectional and longitudinal observational studies, within each of the three health factors. We then address our second goal by presenting findings from studies that have addressed social engagement as an intervention approach.

Relationship Between Social Engagement and Health

Cognitive Health

Our search yielded 13 studies that examined the relationship between social engagement and cognitive health in PwMCI (50–62). Overall, these studies addressed elements related to both activity and network, with a fairly even distribution between the two.

Activity

Seven studies examined components related to social activity, namely type (50, 53, 55, 61, 62), frequency/duration (50, 51, 61, 62), and format (57). No studies included analyses related to purpose or content/topic.

Longitudinal studies that examined cognitive status for PwMCI at baseline observed that higher levels of social activity were associated with a lower risk of progression from mild to severe cognitive impairment (61) and a higher likelihood of reversion from MCI to normal cognition (55). Hughes and colleagues (61) specifically looked at composite measures of both frequency of social activity and types of activities. The authors found that a lower risk of cognitive decline was associated with greater frequency of social activity engagement at baseline, and a slower decline was associated with participation in a variety of social activities across time. A further examination of activity type indicated that participants who progressed were less likely to attend church or worship, less likely to work, and less likely to engage in social organization events (i.e., they participated in fewer formal activities). Shimada et al. (55) similarly found that the type of activity may specifically contribute to the positive effects of social engagement. They examined the rate of reversion from MCI to normal cognition over a 4-year period and found that individuals who did not revert to normal were engaged in social activities less frequently than those who reverted, specifically those who took cultural classes, participated in hobbies or sports activities, or attended meetings in the community. One study, however, did not find an association between the likelihood of conversion from MCI

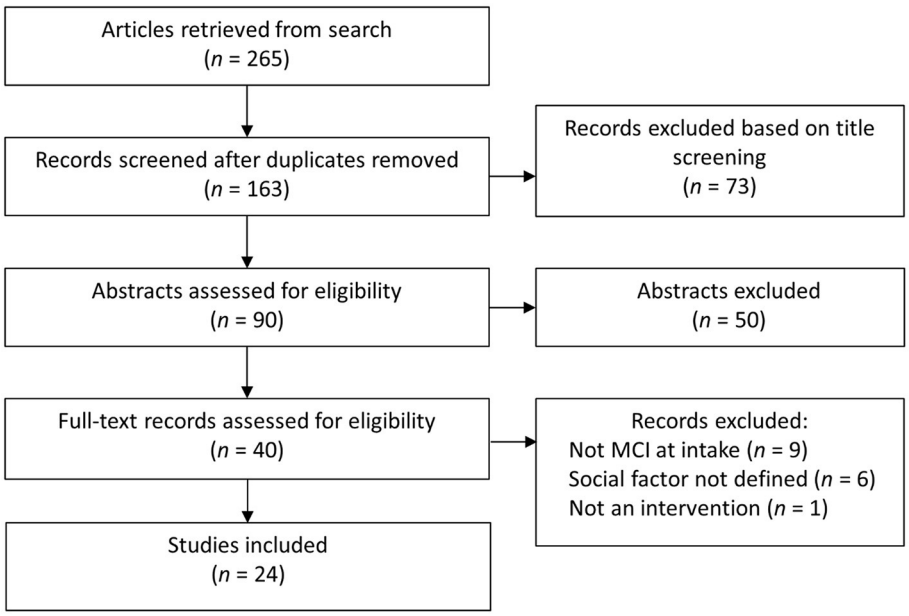

FIGURE 2 | Overview of article selection.

to dementia over a 7-year period and the number of hours spent on social activities (50).

Four cross-sectional studies examined group differences in social activity engagement between PwMCI and cognitively normal controls (51, 53, 57, 62). Nygård and Kottorp (53) found that PwMCI participated less frequently in social activities outside the home relative to cognitively normal controls. Deng and colleagues (51) examined how PwMCI differed from cognitively normal adults on social activities in mid- and late-life and found that those with MCI had significantly less participation in late-life social activities compared to those with normal cognition, but there was no group difference in mid-life social activity. Kotwal et al. (62) examined social engagement in persons with and without MCI and found that those with MCI engaged less frequently in community activities (attending religious services, attending group meetings, and volunteering), but did not differ from controls in frequency of socialization with friends and family. Zhaoyang et al. (57) was the only study to examine format of social activities, wherein participants were asked to provide ecological momentary assessments (EMAs) by responding to prompts on a smartphone five times a day for 2 weeks regarding their daily social interactions. For one of the prompts, participants provided all activities they had participated in over the past 3–4 h, and the frequency of in-person vs. online social activities were summed. PwMCI had 31% lower odds of having in-person socializing each day than those without, but there was not a significant difference in online socializing activities.

Together these studies suggest that PwMCI tended to participate less frequently in social activities, particularly when those activities occurred outside the home, even when controlling for other factors (e.g., sex, race, education). Longitudinal studies indicated that increased frequency of participation in a variety of social activities, especially formal activities with some level of community involvement, may help preserve or even improve cognition and slow progression or reduce risk of dementia in those who already have a diagnosis of MCI.

Network

Nine studies examined components of social network, including frequency of interactions (55, 57, 59), closeness (52, 56, 57), size of network (56, 57, 59, 60, 62), and quality of interactions (54, 57–59, 62).

A longitudinal study that evaluated network size based on living situation and marital status (60) showed that living alone was significantly associated with greater risk of developing dementia, whereas being married/living with a spouse or living with a relative or caregiver was associated with lower risk of developing dementia. Another longitudinal study by Zhang et al. (56) found that having a larger social network was significantly associated with a decreased risk of conversion from MCI to probable dementia. Two cross-sectional studies of network size showed that PwMCI had smaller network sizes compared to cognitively normal individuals (59, 62). The study by Fankhauser et al. (59), which grouped PwMCI and Alzheimer's disease (AD) dementia together, found that network size (i.e., number of social contacts) was positively correlated with cognitive function, measured using the Mini-Mental State Examination. Kotwal et al. (62) examined the proportion of close relationships, described by the authors as network density, in addition to network size and found that lower cognition was associated with greater network density for MCI, with a higher proportion of familial relationships. The authors propose that this could reflect that (i) cognitive challenges make it more difficult to maintain varied

social ties (and thus results in a smaller, denser network), or (ii) a dense, family-focused network serves as a compensatory mechanism where this network can help to monitor and support the cognitively impaired individual. These findings suggest the importance of evaluating not just network size but also closeness in the MCI population. Zhaoyang et al. (57) measured social network size and did not find a difference between cognitively normal older adults and those with MCI; however, this only included the number of close relationships (spouse, family members, and friends).

Zhaoyang et al. (57) examined closeness of social relationships using both EMAs and retrospective global measures that they developed. The EMAs showed that those with MCI had 30% lower odds of interacting with acquaintances, but did not show a difference with other closer social ties (family, friends etc.). Additionally, their global measure of social network included four questions about the composition of their social relationships, and no difference was found between MCI and non-MCI groups. Zhang et al. (56) examined closeness and roles of social ties but did not find a relationship between closeness of ties and risk of converting from MCI to dementia. One qualitative study addressed closeness through their efforts to identify perceived social determinants of health among PwMCI and their care partners (52). Thematic analysis of the dyads' semi-structured interviews revealed a theme of closeness as "connecting with neighbors and community." This was characterized by camaraderie and helpfulness of neighbors, feelings of connectedness with others in the community, and the recurrent/weekly roles of community, family, and church events for PwMCI and their care partners. The authors discussed the possibility that such interactions promote feelings of social connectedness and engagement, which may help to promote cognitive health.

With regard to the frequency of social contacts, Fankhauser and colleagues (59) asked participants to provide the number of children, siblings, relatives, and friends or acquaintances they have contact with, and the frequency of contact. Frequency of social contacts did not differ between persons with cognitive impairment (both MCI and AD) and cognitively normal controls. In contrast, Zhaoyang et al. (57) found that PwMCI had 11% lower odds of participating in social interactions than those without MCI when measured by EMAs. However, no difference in frequency of social interactions was observed when measured with a retrospective global measure. Shimada et al. (55) used a single yes/no question to determine if the participants talked with people every day (format was not specified) and found that PwMCI who reverted to normal cognition engaged in more daily conversations than those who did not revert.

Studies on quality of interactions have examined satisfaction with network, social support, social strain, and negative vs. positive social interactions. Fankhauser et al. (59) did not find a difference in satisfaction with social contact between persons with cognitive impairment (a combination of MCI and AD) and cognitively normal controls. However, they did observe lower levels of social support in persons with cognitive impairment compared to controls. dos Santos et al. (58) similarly found that PwMCI scored worse than controls on a multidimensional scale of social support. Kotwal et al. (62) also observed an association between cognitive status and social support; however, this was moderated by sex, whereby women with lower cognitive scores perceived less social support, but there was no difference for men. They also found that participants with lower cognitive scores perceived less social strain than cognitively normal individuals, perhaps due to reduced social demand from those in their network. Zhaoyang et al. (57) observed that PwMCI had lower odds (14%) of having positive social interactions each day as measured by EMAs, and that the MCI group scored significantly higher on a measure of social strain than the non-MCI group, but scored the same on a measure of social support. Finally, a qualitative study by Renn et al. (54) asked PwMCI to take photographs over the course of 1 week that reflected important aspects of their day-to-day life and then conducted semi-structured interviews using the photographs. Following thematic analysis of these interviews, the importance of social support was a common theme, with participants emphasizing the need for familial support as well as support from and engagement with friends.

In summary, compared to cognitively healthy older adults, PwMCI may have smaller social networks composed of closer relationships and may not feel as socially supported compared to those experiencing typical cognitive aging.

Emotional Health

Four studies examined the relationship between social engagement and emotional health in MCI (63–66). Of these, only one study examined social activity (63), with the other three focusing on social network.

Activity

Amano et al. (63) identified patterns of social engagement by type (informal and formal) and found no relationship between presence of depressive symptoms and activity type.

Network

Three cross-sectional studies examined associations between social networks and emotional health in MCI. Kang and Lee (64) found that higher levels of social support were correlated with reduced depressive symptoms. Additionally, when including various health factors (somatic symptoms, sleep, functional ability), only social support and depression were significant predictors of overall quality of life. Another study found that social network size was correlated with overall quality of life in both persons with and without MCI, but the association was stronger in the MCI group (65). Yates et al. (66) examined how social networks might mediate the relationship between mood (including both anxiety and depression) and the presence of MCI. They noted that PwMCI had greater odds of having anxiety or depression, and generally had lower social network scores on the Lubben Social Network Scale (67), which probes number and frequency of social contacts within two different degrees of closeness (family and friends). They also found that social network score mediated the relationship between mood and MCI, with full mediation achieved only when both the family

and friends subscales were included, indicating the importance of both types of relationships for PwMCI.

Overall, there was a relationship between emotional health and both the structure (e.g., size) and function (e.g., quality) of a person's network. Larger networks and more frequent, high quality interactions may be important for overall mood and quality of life in PwMCI.

Physical Health

Our search yielded six studies that examined the relationship between social engagement and physical health (63, 64, 68–71). The majority of these studies examined the relationship between physical health and social activity, with only one study examining social network (64).

Activity

Five studies addressed physical health as related to social activity. Four of these studies examined activity frequency (68–71) and one examined activity type (63).

Two studies by the same group using the same cohort of participants examined frequency of participation across nine different social activities and its relation to mobility (69) and fall rate (70) in cognitively normal older adults and PwMCI. Although their measure covered a range of different formal and informal social activity types (e.g., go out with others in public places, invite others to your home, provide care to others, volunteer), they did not analyze the effects of type of activity on mobility. In general, they found that MCI was associated with reduced mobility (quantified using both an objective and subjective measure), and activity frequency mediated this relationship (69). Similarly, MCI was strongly associated with number of falls (after adjusting for covariates), and activity frequency (dichotomized into low vs. high) moderated this relationship (70). For PwMCI, low activity frequency was associated with higher fall rate; however, if they had high levels of activity frequency, the association was no longer present. Correspondingly, a study by Gorenko and colleagues (68) found that social activity frequency moderated the association between gait velocity and cognitive status (MCI vs. healthy), whereas physical engagement did not have an effect on this relationship. For those with lower social activity frequency scores, gait velocity significantly predicted cognitive status, whereas for those with higher social activity frequency scores, this relationship was not present. The authors suggest that one potential mechanism underlying the relationship between social engagement, physical health, and cognition is the shared link with inflammation and dysregulation of a stress response. There is also emerging longitudinal evidence that social activity may mediate the link between health conditions (e.g., peptic ulcer recurrence) and sleep quality in PwMCI (71).

A study by Amano and colleagues (63) found that for PwMCI, health factors including self-rated health, number of chronic conditions, and activities of daily living, were significantly associated with type of social engagement (formal vs. informal). Those with higher self-rated health were more likely to engage in formal and informal types of social engagement.

Overall, engaging in social activities had a positive effect on physical health for PwMCI. Specifically, frequency of social activity participation, and participating in both formal and informal activity types, may be related to better physical health in PwMCI.

Network

Only one of the studies from our search related physical health to factors of social network in MCI. Kang and Lee (64) examined the association between social support (i.e., higher quality social network ties), somatic symptoms, and sleep quality within a group of PwMCI. They found that those with higher levels of social support had reduced somatic symptoms and better sleep quality, suggesting a relationship between the quality of a person's network and physical functioning.

Interventions

Three interventions targeted social engagement in PwMCI (72–74). One used an in-person approach (74), whereas the other two used technology-mediated approaches.

In-person

The randomized controlled trial (RCT) conducted by Rovner et al. (74) was designed to prevent cognitive and functional decline among Black PwMCI. Participants in the intervention group attended five in-home behavioral activation therapy sessions (60 min each) over 4 months, followed by six maintenance sessions over the next 20 months. The therapy sessions consisted of goal setting and action plans to increase engagement in cognitive, physical, and social activities. They compared this approach to an active control group receiving standard supportive therapy. The primary outcome measure was cognitive functioning, measured with a single verbal list learning test, with a secondary outcome of physical health status, measured by functional decline. Although increasing social activity was part of the goal setting and action plans, there was no outcome measure related specifically to social activity. In general, they found that the intervention group maintained cognitive and physical functioning, whereas the active control group showed cognitive and functional decline.

Technology-Based

One study examined the feasibility of a virtual pet companion in increasing health outcomes for PwMCI (72). Ten female participants were given a tablet with a virtual pet, such as a dog, displayed on the screen. The device was connected to a call center with trained staff who would listen to the participant and type out responses that were read aloud by the virtual pet. Participants used the companion and reported that they appreciated its presence. Participants scored higher on measures of global cognition and social support and reported reduced depressive symptoms after having the virtual pet for 3 months. However, this study did not have a control group, and had a small sample size.

Another study used a technology-based platform to implement a multimodal RCT for PwMCI, where increasing social engagement was one of the intervention approaches (73).

Participants in the intervention group had daily 30-min face-to-face communications using a web-enabled conversational system, whereas those in the control group received weekly telephone calls during which they were asked what social engagement activities they engaged in that week. The primary outcome was change in cognitive function, with a secondary outcome measure of loneliness. Both the intervention and control groups included persons with and without MCI. Following the intervention, those without MCI showed improvement in verbal fluency scores, whereas PwMCI did not have any significant effects. There was, however, a trend toward increased psychomotor speed for PwMCI. There was no difference between the intervention and control groups on a three-item loneliness scale.

Overall, our search identified few studies in relation to targeting social engagement in MCI. The approaches and targets varied, making it difficult to compare outcomes across studies. However, these results provide emerging evidence to support the benefit of social engagement for PwMCI.

DISCUSSION

Summary of Findings

Our narrative review of the literature largely suggests that there are associations between social engagement and health factors in MCI, but very few intervention studies have targeted social engagement in this population. Positive associations were found across all three health factors (cognitive, emotional, physical) and social engagement, with higher levels of social engagement associated with better health, either directly or through mediating/moderating relationships. However, it is important to note that many of the relationships reported in the literature are derived from cross-sectional data, making it difficult to ascertain the direction of the effects.

The majority of the studies examined the relationship between social engagement and cognition, which is likely because the primary concern of PwMCI is declining cognition. However, the handful of studies examining physical and emotional components indicate that social engagement plays a role in supporting these aspects of health for PwMCI as well and warrant further investigation.

Although the literature points to the importance of social engagement in MCI, very few interventions have targeted social engagement in this population. Social engagement was the primary focus of only one of the three intervention studies reviewed (72). Interestingly, despite the other two intervention studies including social engagement as part of their multipronged approach, the outcomes only focused on cognitive and physical functioning as opposed to social engagement. More work is needed to clarify the role of social engagement in PwMCI and to determine the most effective approaches for intervention.

Gaps in Social Engagement Literature in Relation to Framework

Relationship Between Social Engagement and Health

Keeping in mind that our narrative review provides a broad overview of research on social engagement in PwMCI, we have identified gaps in the current research in relation to our framework (see **Figure 3**). With regard to the two overarching dimensions of activity and network, we noted different patterns across the three health domains. For cognitive health, there was a fairly even distribution of studies examining social activity vs. social network. However, for emotional health the studies focused more on social network, whereas those on physical health focused more on social activity. Perhaps emotional health is thought to be linked to the ability to build relationships, whereas physical health is thought to play a more important role in activity participation. Nevertheless, characterizing both dimensions of social engagement across emotional and physical functioning would provide a more comprehensive understanding of the relationship between social engagement and health.

In further examining the components of activity and network across all health domains, it is clear that certain subcomponents have yet to be addressed in the context of MCI. With regard to activity, studies have primarily addressed frequency/duration and type. Although these components provide some insight into one aspect of their structure (frequency of engagement) and function (type of engagement such as formal or informal), further examination of the other components (e.g., content/topic, purpose) would provide additional insights about the effects of social engagement on health in these individuals. For example, it would be useful to understand if activities that serve different purposes, with various topics, would differentially affect health outcomes. Addressing these components directly would add valuable information. Taken together, such insights could inform the development of interventions, with targets that have the greatest impact on health and quality of life.

Evaluation or manipulation of the format of social activities (i.e., in-person vs. remote) is almost completely lacking in the literature. Given the increased adoption of more remote alternatives to activity participation, it will be important to directly measure differences between in-person vs. technology-based methods of engagement as they may affect health factors differently. For instance, physical health may be a limiting factor for participation in in-person activities, as these often require leaving the home, but this would not be a limiting factor if the activity was occurring remotely. Furthermore, the various components of social engagement may impact health differently depending on the format. For example, formal activities and community involvement may be important for maintaining cognitive health; however, whether such activities need to occur in-person or could be supported online has not been explored.

All four components related to network (frequency, size, quality, closeness) were addressed in at least one of the included studies. Size and quality of engagement were most frequently addressed. Size provides some information about the quantity of relationships, but it only captures part of the picture. Understanding how frequently a person actually interacts with those contacts would be critical to understand its relevance to social isolation and loneliness. This is especially true given that PwMCI appear to have shrinking social networks but may have closer and more frequent contact with network members (62).

Additionally, many studies did not examine more than one component–if they did, they both tended to fall within the

		ACTIVITY					NETWORK			
		Structure		Function			Structure		Function	
		Format	Frequency and Duration	Type	Purpose	Content/ Topic	Frequency of interactions	Size	Quality of interactions	Closeness
Cognitive health	Bidzan et al., 2016 (50)		✓	✓						
	Deng et al., 2019 (51)		✓							
	dos Santos et al., 2018 (58)								✓	
	Fankhauser et al., 2017 (59)						✓	✓	✓	
	Grande et al., 2018 (60)							✓		
	Hughes et al., 2013 (61)		✓	✓						
	Kotwal et al., 2016 (62)		✓	✓				✓	✓	
	Mattos et al., 2019 (52)									✓
	Nygard et al., 2014 (53)			✓						
	Renn et al., 2021 (54)								✓	
	Shimada et al., 2019 (55)			✓			✓			
	Zhang et al., 2021 (56)							✓		✓
	Zhaoyang et al., 2021 (57)	✓					✓	✓	✓	✓
Emotional Health	Amano et al., 2020 (63)			✓						
	Kang & Lee, 2018 (64)								✓	
	Maki et al., 2014 (65)							✓		
	Yates et al., 2017 (66)						✓	✓		✓
Physical health	Amano et al., 2020 (63)			✓						
	Fang et al., 2018 (71)		✓						✓	
	Gorenko et al. 2021 (68)		✓							
	Kang & Lee, 2019 (64)									
	Quach et al., 2019 (70)		✓							
	Steere et al., 2019 (69)		✓							

FIGURE 3 | Framework components addressed by each study.

same dimension (i.e., activity or network). In fact, only four studies measured components within both activity and network (55, 57, 62, 71). Given that social engagement includes both of these dimensions, it is crucial that studies measure at least one component from each to gain a more comprehensive understanding of social engagement in MCI. For example, our review suggests that PwMCI have reduced levels of social support, which may be important for supporting both physical and emotional health. However, we do not know how social activity participation may relate to this finding. Indeed, a recent review noted that a more comprehensive assessment of social engagement can be achieved by viewing it as multifactorial and assessing multiple components and their potential combined effects within a study, as opposed to examining a single component (37). It would be important for studies to characterize activities and networks across all the various structural and functional components to help tease apart the underlying mechanisms for how each relates to health, and to inform the development of interventions that can best serve the MCI population.

Interventions

The evidence about the effectiveness of social engagement interventions for PwMCI is extremely limited. Our search yielded three studies but only two addressed social engagement as an intervention method *and* assessed social health outcomes. One study measured changes in cognitive activity frequency but not social activity (74), and two measured changes in quality of network [loneliness (73) and social support (72)]. Future work should include a more comprehensive assessment of social engagement outcomes across the two dimensions (social activity and network). Also, all three of the intervention studies identified by our search manipulated structural components [increase social activity frequency (74); provide a new "relationship" (72); increase social activity and network size (73)]. The extent to which manipulation of functional components such as type, purpose, and content/topic impacts social engagement in PwMCI warrants further study.

With regard to technology, two of the three intervention studies used technology-mediated methods to deliver interventions, but the extent to which these technologies catered to the needs of older adults with cognitive impairment remains unclear. Some studies suggest there is acceptance of technology within the MCI population (75, 76), but optimizing technology for older adults with MCI before they are used for intervention needs careful consideration.

Measurement Issues and Recommendations

Measures used to evaluate social engagement were highly varied across studies, making it difficult to compare findings. For example, unless the study was completed by the same group of authors, no two studies used the same measure of social activity frequency. Some utilized a fully developed assessment, such as Quach et al. (70) who utilized a subsection of the Late Life

Function and Disability Instrument, whereas others used a few questions developed in-house [e.g., (54, 61)]. This inconsistency may be due in part to the lack of standardized and validated measures of social activity. Social network measures tend to be more consistent, with validated measures such as the Lubben Social Network Index (67) and The Multidimensional Scale of Perceived Social Support (77) being commonly used measures that capture the structure and function of networks, respectively. Examining each of the factors that constitute social engagement is important to tease apart how each may impact or be influenced by health in MCI; however, a single multidimensional scale that fully captures social engagement would also be beneficial (37).

Additionally, it would be useful to utilize more diverse measures of social engagement. The most common form of measurement across studies was a global questionnaire with quantitative scales. However, as pointed out by Zhaoyang et al. (57), given that PwMCI have difficulties with accurate recall, comparisons of activities between persons with and without MCI that require recall from memory may lead to misleading findings unless corroborated by informants. Alternative methods, such as EMAs that collect responses about the present moment at frequent intervals without requiring a recall from memory (57), and semi-structured interviews that collect rich information about an individual's experiences (52, 54) corroborated by informant interviews, can be used to supplement data obtained from validated measures.

Lastly, a barrier to integrating findings from studies of PwMCI relates to the inherent heterogeneity within this population, and the inconsistencies across studies regarding how MCI is diagnosed or defined. For example, some studies relied primarily on a single cognitive screening tool (62–64). Even if a formal diagnosis is not possible, more than one measure of cognitive status should be used to define participants as having MCI and their characteristics should be clearly described.

In summary, we recommend a more comprehensive examination of social engagement that samples both the activity and network dimensions more fully. Future studies should evaluate how the content, purpose, and format of social activity in PwMCI is linked to cognitive, emotional, and physical health. Research characterizing the impact of the quality of interactions and closeness within the network dimension could advance understanding of the extent to which enrichment activities should be planned for PwMCI. Our understanding of the benefits of social engagement for PwMCI is fairly limited. Carefully designing interventions to address various components of social engagement and evaluating outcomes using a battery of measures would be important to establish the value of such interventions for promoting health outcomes. Our framework (**Figure 1**) elucidates the components to consider in the design of social engagement interventions. Finally, as technology access becomes more ubiquitous and affordable, developing technology-based social engagement interventions with broader reach could serve a significant role in addressing social isolation in PwMCI.

AUTHOR CONTRIBUTIONS

RM and WR conceived the primary research question for the study. EL, LN, and QN drafted the initial framework with guidance from RM and WR. EL and LN assessed the papers for inclusion and interpreted the results. EL, LN, and RM drafted the initial manuscript. WR and QN provided input and revision to the manuscript. All authors contributed to the article and approved the submitted version.

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Video Calls for Older Adults: A Narrative Review of Experiments Involving Older Adults in Elderly Care Institutions

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Social isolation in geriatric institutions is a real threat to older adults' (OAs) well-being. Visits from family members, when they are not impacted by geographical distance or illness, sometimes fail to provide sufficient opportunities for social connectedness and interaction to prevent and/or combat OAs' loneliness and social isolation. Information and Communication Technologies (ICTs) offer promising solutions to this problem. Video calls provide a quick and convenient way for remote communication between OAs and their families, and a complement to face-to-face visits in geriatric settings. Over the last months, during the several confinements imposed to stop the transmission of COVID-19 over the world, several care homes and long-care facilities have equipped themselves with laptops, tablets and video call applications to help OAs remain in contact with their relatives. However, numerous technical and human-related factors may hinder the use of video calls in these settings. The complexity of technological devices, as well as OAs limited digital skills, low confidence and experience in the use of technology are some examples. Furthermore, the specific context of use and the required implication of multiple actors (care professionals, family members) should also be considered when examining the use and implementation of video calls in geriatric institutions. We conducted a narrative review of literature describing the use of video calls in geriatric institutions between 2000 and 2021, especially because of the little information related to OAs' use of video calls in geriatric settings. One thousand one hundred ninety-seven references were screened and 15 studies focusing on the usability, acceptability and effectiveness of video calls were included. A qualitative, deductive thematic analysis inspired by a Health Technology Assessment (HTA) multidimensional model was used to identify barriers, enablers and solutions to video calls implementation in geriatric institutions. The results from the HTA-based analysis provide encouraging evidence for the feasibility of video call use in geriatric settings, and its efficacy on reducing social isolation among residents. However, numerous technical, human-related, ethical and organizational barriers persist and should be addressed in future works. The present analysis has also allowed the identification of potential solutions to overcome these barriers, which are discussed in this publication.

Keywords: older adults, video calls, elderly care institutions, social isolation, health technology assessment (HTA)

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INTRODUCTION

Social isolation and loneliness represent a serious issue among older adults living in geriatric institutions. Current literature shows that the prevalence of loneliness among nursing home residents is estimated between 50 and 55% (1–3). Indeed, the difficulties to establish new relationships due to health conditions and/or the need for functional assistance (4), or the decline of family visits over time (5), contribute to loneliness and social isolation in this population, at the expense of their well-being (6), quality of life (7) and cognitive functioning (8). With the COVID-19 pandemic and the resulting lockdowns and confinements, elderly care institutions in many parts of the world were instructed to stop all social activities that might put residents at risk (9). As a result, this population, already affected by problems of social isolation, has seen the number of visits decrease drastically (10), increasing their feeling of loneliness and abandonment (11, 12). In an attempt to help OAs maintain richer social interactions at distance than those that may be possible with traditional telephone calls, many geriatric institutions took up or renewed their interest for video calls.

Video calls are a remote communication service offered by several software programs such as Skype (13), Zoom (14) or WhatsApp (15), used to speak with other persons and see them simultaneously on video. Several technologies support these video communications services such as videophones, computers, tablets, smartphones and more recently, mobile telepresence robots (16). The diversity of technological supports, now available for video calls, has introduced new types of user interfaces (e.g., touch, graphical, vocal) (17). In this way, physical pushbuttons and handsets have been progressively replaced by computer mouse, touchpads or touch screens of various sizes. Those technological advances have changed the way users interact with the devices, requiring cognitive and physical capacities which can decrease with age especially if older adults have somatic sensorial or cognitive disorders (18). The rapid development and accessibility of these technologies over the past years has favored the use of video calls (19, 20). More recently, the COVID-19 pandemic contributed to popularize them by highlighting their value as social connector (21), especially as OAs living in geriatric institution lose their traditional social ties. However, a wide availability of these Information and Communication Technologies (ICTs) does not lead to an adoption in elderly care institutions (22–27). Evidence suggests that many technological, individual and contextual factors can influence the use and adoption of ICTs by OAs (10, 28).

Lee and Coughlin (29) identified 10 factors that determine OAs' use and adoption of ICTs products and services, among them: the perceived usefulness and potential benefits of the technology (value), the ease of learning and use (usability), its perceived costs (affordability), its availability (accessibility), the possibility of receiving help if needed (technical support), support received from family, peers and community (social support), the perception of emotional benefits (emotion), the perception of how a technology makes them look to others (independence), OAs' level of experience and confidence in using the technology. According to these authors, these factors are interrelated and have a collective influence on technology acceptance, use and adoption. In the specific case of video call systems used in institutional care contexts, another aspect that must be considered is the required involvement of several actors for the use of the technology, the resident (OA), the family member(s), and the care worker who usually helps during the video call. The study of the implementation and adoption of video call services in the context of geriatric institutions must accordingly consider the perspectives of the multiplicity of actors.

Understanding the barriers and enablers to using video calls in a specific context, such as geriatric care institutions, requires conducting a multidimensional analysis considering, for instance, human, organizational, technological and ethical aspects. However, a few articles in this field have tackled those aspects using a comprehensive approach (30, 31). A recent literature review used a multidimensional analysis method to examine factors for success or failure of mobile telepresence robots' implementation, including video calls functionalities, with OAs at home or in institutions (31). However, the review focused more on the robotic technology itself, than on the implementation of related services. Schuster and Hunter (30), in a scoping review, offered a global analysis of the implementation of video calls in geriatric institutions. Their objective was to describe the use of video calls with institutionalized cognitively intact OAs. Results from the analysis of five studies suggested that video call systems were useful to improve connectedness between OAs and families. However, the perspectives of each actor and their particular barriers were only very briefly described. The authors suggested that further works should explore contextual factors that would help to better understand the feasibility for video communication from the institution perspective (e.g., training needs, organizational aspects), especially as video calling technologies could be valuable tools to fight loneliness, provided that they are implemented strategically (19).

In this sense, the multidimensional analysis models used in the field of Health Technology Assessment (HTA) could provide an analysis grid that questions the clinical, human, technological, medico-economic, ethical and legal aspects of an intervention. This analytical framework makes it possible to assess the global value of a health technology (i.e., its properties, and the effects and repercussions of its implementation) (32). It could be therefore interesting and relevant to study the use of video calls in institutions for OAs using these multidimensional HTA analysis models.

The objective of this review was first to identify barriers, enablers, as well as solutions for the implementation of video calls in elderly care institutions, using a multidimensional HTA approach for the analysis of experimental results presented in publications in the literature, and second to explore the benefits of this service on the maintenance of OAs' social interactions.

MATERIALS AND METHODS

Data Sources and Search Strategy

The aim of this literature review was to analyze published studies describing the experimentation of video call interventions

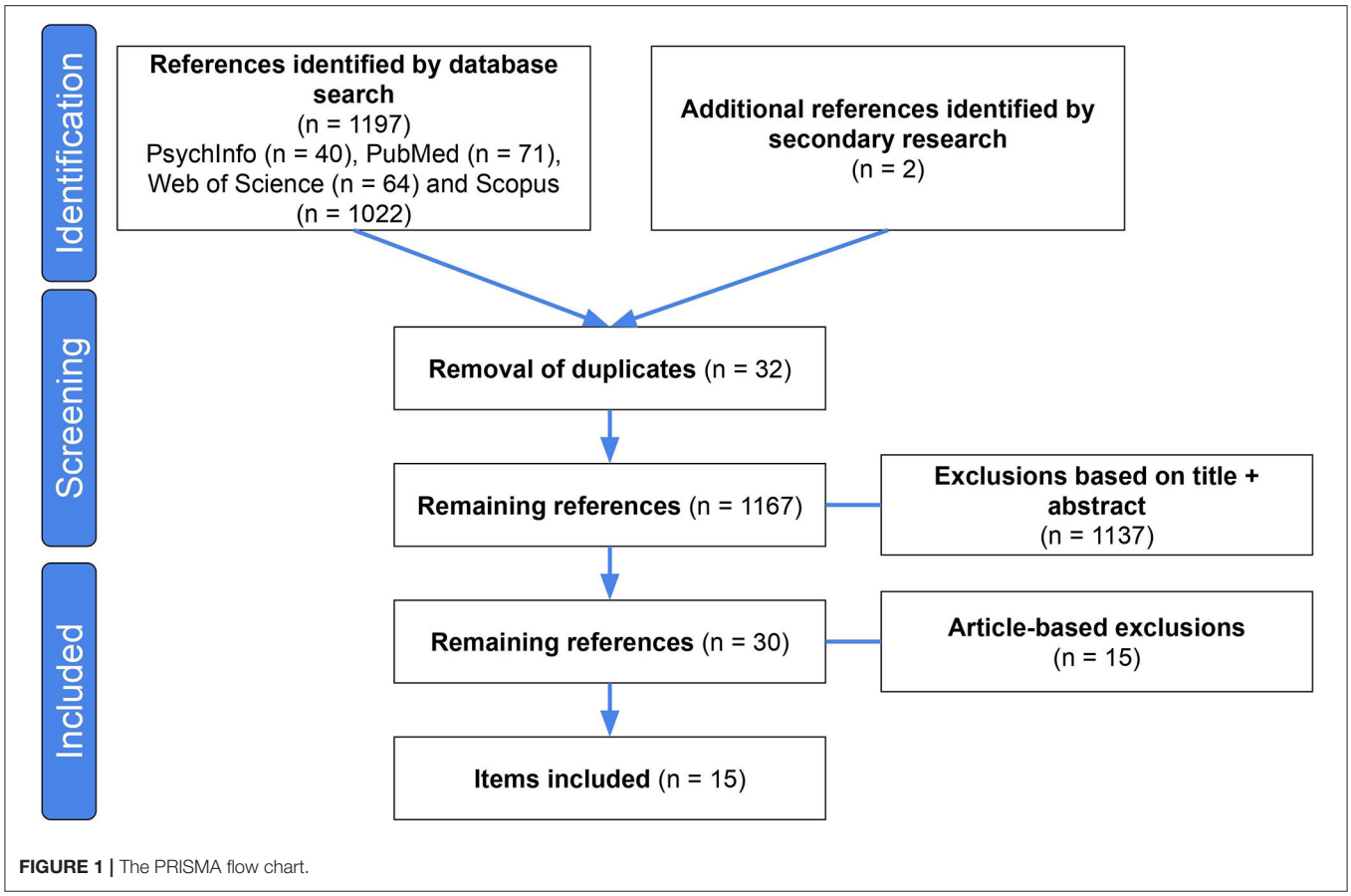

FIGURE 1 | The PRISMA flow chart.

in elderly care institutions. Based on the PICo (population, interest, context) method (33), we developed the following research questions: "*What are the barriers, enablers and benefits for the use of video calls by OAs in elderly care institutions and what solutions could be considered to overcome those barriers and take advantage of those enablers?*." The keywords for conducting the search were grouped into three categories: *elderly, nursing homes* and *video calls*. A systematic search was first conducted consulting the following databases: PsycINFO, PubMed/Medline, Web of Science and Scopus. The search was carried out between March and June 2021. We reviewed studies published between January 2000 and June 2021. As with Schuster and Hunter (30), we allowed for a very broad span of time for the inclusion of publications (2000–2021), especially because of the little information related to OAs' use of video calls in geriatric settings. We then searched for studies conducted during the COVID-19 pandemic using keywords grouped into four categories: *elderly, nursing homes*, *video calls* and *COVID-19*.

The criteria for the inclusion of studies in the review were as follows: (a) experimental studies involving OAs using video call technologies and functionalities, (b) studies describing a video call intervention or activity conducted in a geriatric care institution (e.g., nursing home, assisted living, geriatric service or hospice facility), (c) publications describing an experimental study regardless of the study design (e.g., observational study, case control, randomized study, qualitative study), (d) studies written in English or French. Publications were excluded if: (a) participants gave their opinions only based on photos or videos of video call technologies, without actually using them, (b) studies described experimentations using mobile telepresence robots as a support for video calls.

To guide the literature selection process, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (34) was used. The study selection was done based on the title, abstract, or full article. Then, a secondary search using the internet and references from other articles was carried out according to the same inclusion criteria. When several publications dealt with the same project, only the publication giving the most detailed information about the work was selected. The flow chart describing the search and study selection strategy is shown in **Figure 1**.

The Health Technology Assessment Model

We examined barriers, enablers, as well as solutions to the implementation and use of video calls in geriatric care institutions, as reported in the publications, using the European Health Technology Assessment model (EUnetHTA Core Model®, version 3.0) created by the European Network

of HTA (35). Although the main aim of the HTA Core Model is to enable international collaboration in producing HTA information, its ontology can be used in other tasks related to the development, utilization and assessment of health technologies (32). Proper registration of the use of EUnetHTA Core Model®, version 3.0 for this work was made on the HTA Core Model® website (36).

The EUnetHTA core model® version 3.0, is composed of nine domains, each one including several topics, each topic includes as well different issues (i.e., questions that should be considered for the evaluation of a health technology). The model is thus structured into three levels: "Domain" (*level 1*), "Topic" (*level 2*), and "Issue" (*level 3*). The combination of a domain, topic and issue is linked to an assessment element ID, which can be identified using a specific code for standardization purposes (e.g., B0001, B0002…). An example of this combination is presented in **Table 1**. Main EUnetHTA model domains are: 1. Health and Current Use of the Technology (CUR), 2. Description and Technical Characteristics of Technology (TEC), 3. Safety (SAF), 4. Clinical Effectiveness (EFF), 5. Costs and Economic Evaluation (ECO), 6. Ethical aspects (ETH), 7. Organizational Aspects (ORG), 8. Patient and Social aspects (SOC), and 9. Legal Aspects (LEG). A description of each domain is available in **Table 2**.

TABLE 1 | An excerpt of the Safety (SAF) and Technical Characteristics of Technology (TEC) domains of the EUnetHTA core model.

Domain	Topic	Issue	Assessment element ID
Safety (SAF)	Patient safety	What are the susceptible patient groups that are more likely to be harmed through the use of the technology?	C0005
Safety (SAF)	Safety risk management	How can one reduce safety risks for patients? (including technology-, user-, and patient-dependent aspects)	C0062
Description and Technical Characteristics of Technology (TEC)	Features of the technology	Who administers the technology and the comparators and in what context and level of care are they provided?	B0004

Data Extraction and Analysis

For each publication included in the review, a systematic data extraction was done to summarize: (a) the intervention objectives, (b) the participants' characteristics, (c) the conditions of the experimentations (technology used, duration), (d) the methodology of the study (study design, inclusion of a control group or not assessment tools used), (e) the barriers and enablers to the implementation of the technology (if described), (f) the benefits of the intervention on social interactions (if described), (g) the solutions to overcome barriers to the implementation of the technology (if described).

Then we conducted a theoretical or deductive thematic analysis of the studies using the EUnetHTA Core Model® as a framework. In this "top down" modality of thematic analysis, data is coded and interpreted according to categories or constructs from the existing literature (37). In our case, EUnetHTA domains, topics and issues were used as a set of pre-defined codes to guide the process of data interrogation and organization. Thus, we first identified in each article (methods, results and discussion sections) segments of data that were relevant or captured an idea linked to key concepts of EUnetHTA domains (*level 1*). We proceeded then to a first coding cycle (i.e., label the segments of data). A subsequent exploration of the data coded (sentences or set of statements) was made to get a more analytical identification and defined at the topic level (*level 2*) or at the issue level (*level 3*); corresponding coding was then made using the HTA nomenclature. A semantic approach was used to identify themes and codes using the explicit or surface meaning of the data and not the underlying assumptions or ideas (38). A thematic analysis using EUnetHTA framework for a literature review has been described in another study (31). The 14 selected articles were all coded using this methodology and the software package MAXQDA.

TABLE 2 | Domains of assessment of the EUnetHTA core model (EUnetHTA Joint Action 2, 2016).

Domains	Main features
Health and Current Use of the Technology (CUR)	The condition targeted by the technology, the therapeutic purpose of the intervention, and the current standard treatment to address it.
Description and Technical Characteristics of Technology (TEC)	The technical features of the technology, its level of maturity, the resources (material, infrastructural, etc.), and skills required to use it.
Safety (SAF)	The risk and unwanted effects caused by the technology, and the way to prevent and manage it.
Clinical Effectiveness (EFF)	The effects of the intervention on the ability to reach the clinical objectives set for the intervention, on the condition of the quality of life and the autonomy of the users, as well as on the follow up conduct by the professionals who take part in the intervention.
Costs and Economic Evaluation (ECO)	The costs, the health-related outcomes, and economic efficiency of the technology.
Ethical Analysis (ETH)	Issues related to ethics and values when using health technology.
Organizational Aspects (ORG)	The allocation of resources (material artifacts, skills, knowledge, money, work culture, etc.) required to implement the technology in the organization and the healthcare system.
Patients and Social Aspects (SOC)	The representations conveyed by the intervention at the individual's and collective's levels, for the patients, their entourage, the caregivers, and society as a whole.
Legal Aspects (LEG)	The regulations and laws to be considered in evaluating a technological intervention.

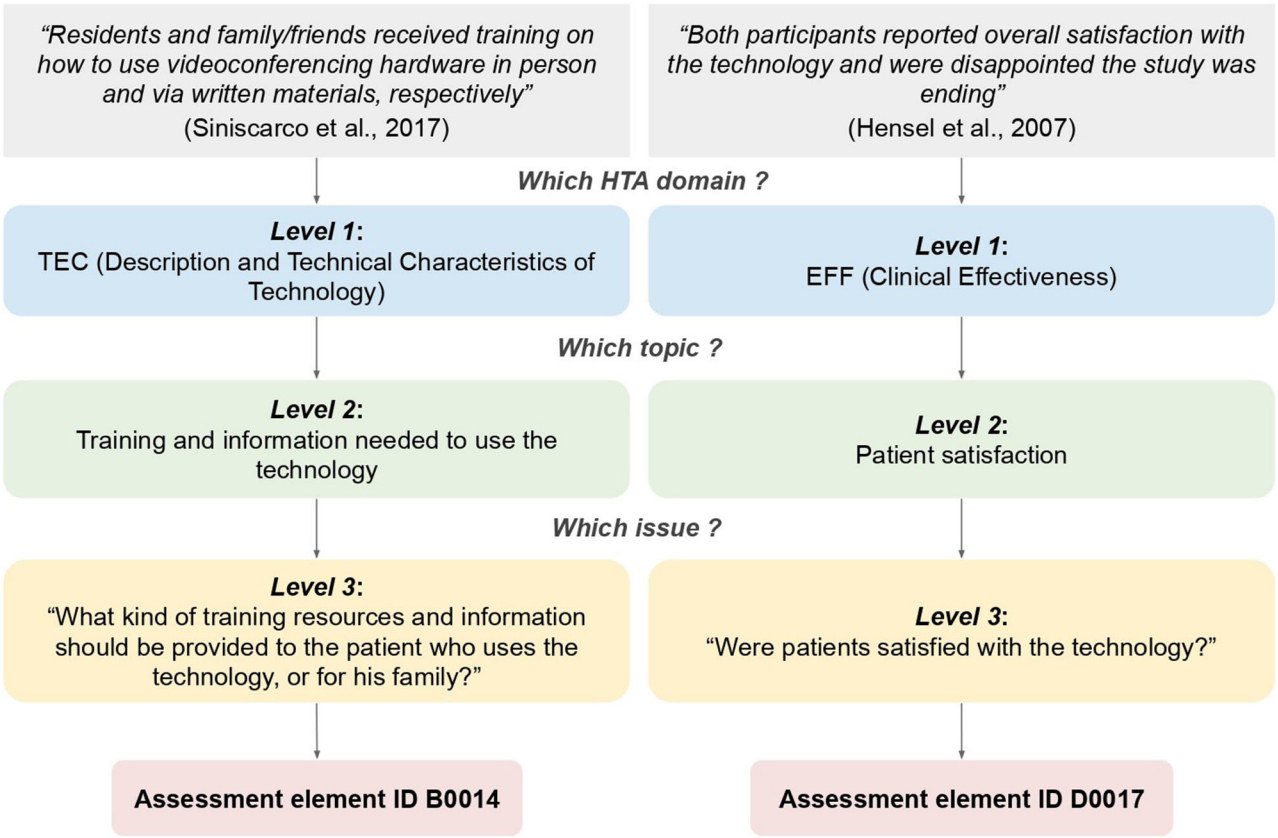

FIGURE 2 | Examples of data coding for the inductive thematic analysis using the EUnetHTA framework.

For instance, in the following excerpt from one of the studies selected: "*Residents and family/friends received training on how to use videoconferencing hardware in person and via written materials, respectively*" [(24), p. 320]. Siniscarco et al. described the intervention protocol for using the video calls system, especially the training and information given to the OAs and their family members. Using the EUnetHTA-based coding system, the domain "Description and Technical Characteristics of Technology (TEC)" (level 1) was identified and assigned, then the topic "Training and information needed to use the technology" (level 2) was identified and coded, and finally the issue "What kind of training resources and information should be provided to the patient who uses the technology, or for his family?"(level 3) was also identified and coded. To conclude, the assessment element ID for the corresponding combination Domain, Topic and Issue was added (B0014).

Following the same methodology, in the following excerpt from another one of the studies selected: *"Both participants reported overall satisfaction with the technology and were disappointed the study was ending*" [(39), p. 124], Hensel et al. claimed that participants were satisfied with the video calling technology. Coding proceeded as follows: EUnetHTA-based domain "Clinical Effectiveness (EFF)" (*level 1*) was identified and assigned, then the topic "Patient satisfaction" (*level 2*) and the issue "Were patients satisfied with the technology?" (*level 3*) were also identified and coded. Finally, the assessment element ID for the corresponding combination Domain, Topic and Issue was added (D0017). Those examples are presented in **Figure 2**.

RESULTS

General Findings

A total of 15 studies were included in this analysis. The studies were published between November 2002 and December 2020. They were conducted in different world regions: North-America (United-States of America) (22, 24, 39, 40), Asia (Taiwan) (23, 27, 41, 42), Europe (25, 26, 43–46), and Oceania (Australia) (47). Regarding the type of institution in which the video calls intervention was conducted, different types of geriatric care institutions were cited: "nursing home" (22–24, 27, 39, 41, 42, 44, 45, 47), "care home" (25, 43, 46), "geriatric hospital" (25, 26, 44) and "assisted living retirement facility" (40). Most video calls interventions used as a support a "touch-screen tablet" (n = 5) followed by a "videophone" (n = 4), with the remainder using either a "laptop" (n = 2), a "smartphone" (n = 1), a "tabletop" (n =1), or a "TV" (n = 2). Three different software programs, such as "Skype" (n = 8), "Line" (48) (n = 2) and "MSN (Microsoft Social Network, Windows Live Messenger)" (49) (n = 2) were used on tablet, laptop, smartphone or TV. The length of experimentation reported in the studies ranged from 1 day

TABLE 3 | General description of the selected studies.

Study	Country	Technology used (application)	Time period	Type of geriatric care
Mickus and Luz (2002) (22)	USA	Videophone	6 months	Nursing Home
Sävenstedt et al. (2003) (45)	Sweden	Videophone	3 to 18 months	Nursing Home
Hensel et al. (2007) (39)	USA	Videophone	3 months	Nursing Home
Demiris et al. (2008) (40)	USA	Videophone	3 months	Assisted Living, Retirement Facility
Tsai et al. (2010) (27)	Taiwan	Laptop (Skype, MSN)	3 months	Nursing Home
Tsai and Tsai (2011) (23)	Taiwan	Laptop (Skype, MSN)	12 months	Nursing Home
Siniscarco et al. (2017) (24)	USA	Tabletop (Skype)	2 months	Nursing Home
Zamir et al. (2018) (25)	UK	Tablet (Skype)	15 months	Care Home, Geriatric Hospital
Chiu and Wu (2019) (41)	Taiwan	Tablet (Line or Youtube)	12 weeks	Nursing Home
Moyle et al. (2019) (47)	Australia	Tablet (Skype)	1 day	Nursing Home
Niebler et al. (2019) (26)	Germany	Tablet (Skype)	NP	Geriatric Hospital
Tsai et al. (2020) (42)	Taiwan	Smartphone (Line)	6 months	Nursing Home
Sacco et al. (2020) (44)	France	NP	2 weeks	Nursing Home, Geriatric Hospital
Carcavilla et al. (2020) (43)	Spain	TV (Skype)	6 weeks	Care Home
Zamir et al. (2020) (46)	UK	Tablet and TV (Skype)	8 months	Care Home

MSN, Microsoft Social Network (Windows Live Messenger); UK, United Kingdom; USA, United States of America; NP, Not Precised.

to 18 months. A general description of the included articles is presented in **Table 3**.

Concerning the methodological aspects, the majority of the study designs were "exploratory qualitative studies" ($n = 5$), "randomized trial" ($n = 3$) or "ethnographic and a part of a Collaborative Action Research (CAR)" ($n = 2$), the remaining ones were a "case study" ($n = 1$), a "randomized longitudinal trial" ($n = 1$), an "exploratory mixed-methods study" ($n = 1$), a "cross-sectional study" ($n = 1$), or a "quasi experimental study" ($n = 1$). Regarding the main objective of the assessment described in the studies, more than half addressed the feasibility and acceptance of video calls technologies, notably through the study of their usability and usefulness, the other half studied the clinical impact of video calls on loneliness or depression. Finally, the majority of the studies involved both healthy OAs and OAs with cognitive impairments ($n = 12$). However, the severity of the impairments remained unclear. Only a few publications reported explicitly involving OAs with severe cognitive decline (dementia) ($n = 3$). A summary of the methodological features of the studies is presented in **Supplementary Table 1**.

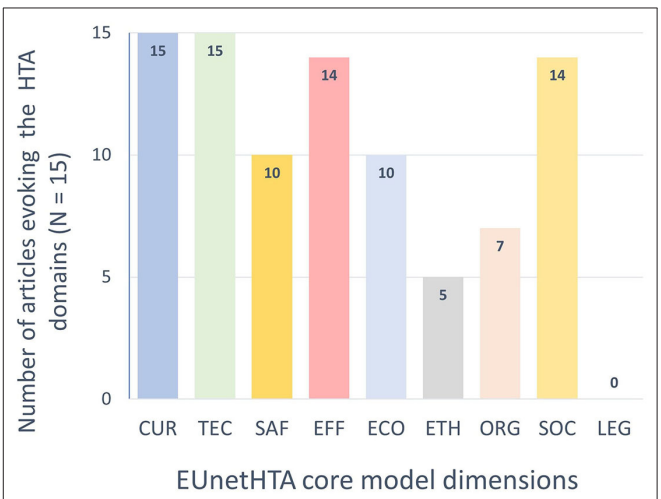

FIGURE 3 | EUnetHTA core model domains occurrences within the 15 selected articles.

Description of Studies Using HTA Dimensions Including Topics and Issues When Available

In the following section the HTA-based thematic analysis of the studies' findings is presented using the three levels of analysis of the EUnetHTA model, described in Methods. Each segment refers to one of the nine major EUnetHTA domains (CUR, TEC, SAF, EFF, ECO, ETH, SOC and LEG). Then, data that refers to the next two EUnetHTA analysis levels "Topics" and "Issues" are described. The EUnetHTA core model® version 3.0 assessment element ID is provided for each issue described.

A summary of the distribution of HTA domains by articles is shown in **Figure 3**.

Population, Health Problem and Current Use of the Technology (CUR)

Target Population

Issue: "What Is the Target Population in This Assessment?" ID (A0007). In all the studies included (100%, $n = 15$), the target population for the interventions using video calls was "OAs living in elderly care facilities." These institutions were: nursing homes (22–24, 27, 39, 41, 42, 44, 45, 47), care homes (25, 43, 46), geriatric hospitals (25, 26, 44), and assisted living retirement facilities (40). Target populations in the studies were either healthy OAs, suffering from mild cognitive impairment (MCI) (22–25, 27, 39–43, 46, 47), or a major cognitive impairment, including dementia (26, 44–46).

Target Condition

Issue: "What Aspects of the Consequences/Burden of Disease are Targeted by the Technology?" ID (A0009). The aim of video calls interventions was to target socialization need of OAs living in institutional settings. OAs living in elderly care institutions frequently experienced loneliness, infrequent social contact with their relatives or friends, a lack of meaningful relationships, and/or difficulties in forming new relationships (24, 41, 43, 45, 46).

Current Management of the Condition

Issue: "What are the Other Typical or Common Alternatives to the Current Technology?" ID (A0018). Before the implementation of video calls in elderly care institutions, OAs already had their own habits, like regular in-visits or telephone calls. Several studies refer to existing modes of socialization with relatives that may compete with video calls. Most of the studies mentioned face-to-face visits (22, 25, 26), followed by telephone calls (22, 47), and finally letters (22).

Utilization

Issue 1: "For Which Health Conditions and Populations, and For What Purposes Is the Technology Used?" ID (A0001). Video call interventions were offered to OAs living in geriatric care facilities to reconnect with families, facilitate interactions, or maintain social connectedness (23–25, 27, 40–42, 45). The other publications did not mention any precise utilization purpose of video calls (22, 26, 39, 43, 44, 46, 47).

Issue 2: "Is the Technology a New, Innovative Mode of Care, an Add-on to or Modification of a Standard Mode of Care or Replacement of a Standard Mode of Care?" ID (F0001). In two studies, video calls were considered to be an additional means of long-distance communication (26, 47), and one better than the traditional telephone (22). In cases where the family could not visit their loved one, or where such visits were too demanding for them, video calls could be used to replace them (22, 39, 44). Finally, video calls could also be part of a leisure activity offered to residents by staff members (43, 46).

Description and Technical Characteristics of Technology (TEC)

Features of the Technology

Issue 1: "What is This Technology and the Comparator(s)?" ID (B0001). Studies experimented and assessed video calling technology. Video calls allow face-to-face contact during a call (associating audio and video) and can be used on different technological supports. Among the 15 studies reviewed, six different video calling technologies were used, as well as three different freeware programs. Two of them are instant messaging and video calling applications (e.g., MSN, Line), while the other one provides only video calls services (e.g., Skype). Detailed descriptions of these technologies, how they were used, and in which settings are presented in **Supplementary Table 2**. One study specified neither the equipment nor the software program used (44), six others did not specify technical issues (23, 27, 41–43, 45), and three did not specify the setting (27, 40, 43), and frequency of use (22, 26).

Issue 2: "Who Administers the Technology and the Comparators and in What Context and Level of Care are They Provided?" ID (B0004). For the use of video calling technology, OAs were either independent (22, 39, 42, 44), partially assisted by facility staff (22–24, 27, 41, 42, 44, 47), or completely dependent on external help (25, 26, 45, 46). In some cases, even if the OA was independent when using the technology, it was usually family members who initiated the calls (22–25, 39, 45).

Issue 3: "What Is the Claimed Benefit of the Technology in Relation to the Comparators?" ID (B0002). After introducing video calling technology and services in the geriatric facilities, residents, families and care staffs reported different benefits. Among them, the most cited was the fact of being able to have richer and more emotional conversations, compared to traditional calls, by the addition of the video dimension (22, 39, 40, 44–46). This visual dimension seemed to provide a real psychosocial support to the resident (26). In this regard, video call interventions could become an integral part of the care process. Video calling was also helpful to overcome "social barriers" and help OAs to reconnect with their families and friends when they had been distant and had no or little contact (41). Another advantage of video calling technologies was the possibility of using them anywhere thanks to their mobility (25, 42).

Investments and Tools Required

Issue: "What Material Investments are Needed to Use the Technology?" ID (B0007). Video calling intervention implies some material investments (e.g., hardware, software, Wi-Fi access, supports…). **Supplementary Table 2** describes the equipment and services used in the studies for conducting video call interventions. In some studies, basic video calling technology was "disguised" or furnished to improve the user experience and perceived usability by residents. Four studies using the tablet included a support to avoid the need for the resident to hold it [e.g., wheel support (25, 46), traditional support (26, 41)], and three added a traditional handset to reassure the participants about the video calls, but also to help them understand the use of the tool (25, 26, 46). Finally, only one study proposed a sensor pen in addition to the tablet support to facilitate the use of the touch screen (41), and two others had to improve the ergonomics of the tool to make it more accessible (large, bright, raised numbers on the keypad or phone with volume control) (22, 24).

Training and Information Needed to Use the Technology

Issue: "What Kind of Training Resources and Information Should be Provided to the Patient Who Uses the Technology, or For his Family?" ID (B0014). In order to correctly use video call technology and services, training or information sessions may be necessary for users. Among the selected studies, six did not specify this information (39, 40, 43–46), and four did not provide information to the OAs, with staff members being designated to use the technology for them (22, 23, 25, 26). Only seven

studies devoted time at the beginning of the experiment to, at a minimum, informing OAs about how video calls work on the designated tool. In one study, the researchers preferred one-on-one training where they first showed the resident and family how the tool worked, rehearsed just before the first call, attended the first call, and finally provided a reminder of the instructions on paper (22). A second study preferred a group training (about 10 OAs), with a 1.5-h session every week for 12 weeks. These sessions consisted of general information about the tool and its functionalities, but also practical exercises with reminders at the beginning of each session about the actions seen in the previous session (41). In the remaining studies, the researchers simply showed, informed, or had the resident practice once before the video call intervention took place (24, 26, 27, 42, 47).

Safety (SAF)

Patient Safety

Issue: "What are the Susceptible Patient Groups That are More Likely to be Harmed Through the Use of the Technology?" ID (C0005). Regarding the safety of OAs who took part in the video call intervention, some staff members expressed concerns about physical risks linked to the use of video call technologies [e.g., fear of hurting residents when moving the "Skype on Wheel" (SoW) tool (a tablet on a wheeled support) through the hallways] (25). In addition, some unwanted and harmful psychological risks were described, for instance, a professional emphasized the anxiety-inducing aspect of the tool when entering the resident's room. Indeed, one resident showed anxiety and confusion when he saw the tool arrive in his room (25).

Also, regarding psychological risks, it was noted that many participants expressed frustration or even confusion with the many connection, audio, or video issues that disrupted calls (22, 24, 25, 40): "*she grew concerned that her family did not want to speak to her*" (25).

Furthermore, the technology itself could be intimidating some OAs, confronting them with their own physical and/or cognitive difficulties and disabilities (24, 25, 41, 47). One resident was afraid of "*looking silly trying to use video calls*" (25). This apprehension of new technologies may also echoed their perceived vulnerability, to something they did not control or understand. An example of this was the fear of having their own identity stolen by hackers (26, 47).

Finally, some residents with dementia expressed fear that video call technology would replace visits from their loved ones (45), who would see it as a way to alleviate their obligation to visit their relative (26). Finally, these same residents did not always seem to understand the concept of video calls. Although they recalled talking to other OAs, they did not recall using a videophone tool (46). This discrepancy could lead to confusion among these already anxious residents (25).

Safety Risk Management

Issue: "How Can One Reduce Safety Risks For Patients (Including Technology-, User-, and Patient-dependent Aspects)?" ID (C0062). To reduce the risk of confusion and anxiety about the video call technology, some care staff suggested "disguising" the video call equipment. The goal was to make it more user-friendly (25). As far as technical problems are concerned, no solutions were discussed in the publications. As the problems were mostly due to a bad internet connection, there was no way to resolve them immediately and in real time (38). On the other hand, audio and video problems seem to have decreased or even disappeared with the appearance of tablets, computers and smartphones.

Clinical Effectiveness (EFF)

Morbidity

Issue: "How Does the Technology Affect Symptoms and Findings (Severity, Frequency) of the Disease or Health Condition?" ID (D0005). The use of video calls in an elderly care facility can have an effect on health outcomes of the target population. Two studies found a decrease in depressive symptoms experienced by most residents (15, 19, 34). Another study found a positive effect on pain, vitality and physiological health of OAs (34).

Health-related Quality of Life

Issue: "What Is the Effect of the Technology on Generic Health-related Quality of Life?" ID (D0012). The use of video calls can also affect the health-related quality of life. The main reported benefits of its use were the improvement of the users' well-being (24, 41, 46), a better self-perception (42) and self-esteem (43). Thus, some participants reported feeling younger or feeling in tune with the younger generation. In addition, the use of video calls was also associated with a decrease of loneliness (23, 24, 27, 42), and social isolation (24). Other benefits on the general well-being of the person were also observed, such as an improvement of quality of life (mental component) (41).

Regarding the interactions between the participants and their relatives, video calls seemed to improve family and friend social support (41). The effect of video calls on the quality and quantity of social interactions were not unanimously acknowledged by the authors. Some observed an increase in the number of social interactions (40, 46) and/or in social connectedness (22, 40, 46), especially regarding remote communication in non-verbal participants (22), while other observed no changes, either in terms of quantity (22), or quality (23). Some OAs who benefited from video calls reported a feeling of closeness with the family, such as the feeling of "*still [being] part of the family*" (40).

Beyond the feeling of being integrated, a real feeling of presence was associated with the use of video calls. Indeed, many participants reported that: "*It was like having him [the family member] in the room with me [OA]*" (24); "*The visual aspect helped me to feel like I was visiting when we spoke*" (40). This feeling of presence was stated in four studies (23, 24, 39, 40). Through the improvement of emotional support (15, 16, 19), informational support (24), and appraisal support (Social Support Behaviors scale) (23, 27), video calls finally helped to reassure elderly participants about the health status of their relatives (39).

Finally, video calls in general offered a new activity, a distraction to the residents to combat boredom and to help them "pass the time" (31). Thus, residents seemed to "regain a sense of self and purpose again" (46).

Patient Satisfaction

Issue: " Were Patients Satisfied With the Technology?" ID (D0017). Studies that reported users' feedback (OAs and family members) described a good level of satisfaction of using video calls to communicate with their loved ones (22, 24, 26, 39–41, 44, 45).

In one study, a family member declared that his elderly relative seemed more relaxed and focused on the conversation during video calls than in traditional visits (45). A study reported that OAs looked forward to occupational activity sessions using video calls, since these were integrated into a leisure and game context between nursing homes where "*winning became our home's pride*" (46). Indeed, some authors suggested to embed video calls sessions into a more global social interaction activity such as arranging for family members to have a meal together with residents via videoconferencing (23).

Finally, a few studies reported that some participants rejected video calls, notably because of technical problems previously described in section Description and Technical Characteristics of Technology (22, 24), but also because of a poor acceptance of the equipment itself (26). The situation could then quickly become a source of anxiety for the residents, some showing confusion caused by the perceived complexity of the technology, among other things (25, 26). Finally, one participant did not see any value in video calls because of her vision impairment (22).

Organizational Aspects (ORG)

Health Delivery Process

Issue 1: "How Does the Technology Affect the Current Work Processes?" ID (G0001). The implementation of video calls in geriatric institutions may require the involvement of facility staff members, which impacts their work and the care process. In eight studies, staff members assisted (22, 42, 44), or organized and implemented video call interventions (23, 25, 26, 45, 46) in addition to providing care to OAs. The use of video call technology added an additional task to an already busy schedule, increasing their workload (25, 26, 46). In one study, staff members declared as well that their priority was to ensure physical care: "*families need us [staff members] to focus on the care*" (46). Depending on the conditions imposed by experimentation, video calls could be made once a day (44, 45), once a week (23, 42), or once a month (25, 46).

Issue 2: "What Kind of Process Ensures Proper Education and Training of Staff?" (G0003). To ensure proper assistance to OAs with the use of video conferencing technology, researchers trained staff members (23, 25), held an event to introduce the technology (26), or simply demonstrated how it works to staff members (22).

Structure of Health Care System

Issue: "What Are the Processes Ensuring Access to the New Technology For Patients/Participants?" ID (G0101). In cases where facility staffs were directly involved in the use of video calls, different processes were implemented. Some facilities practiced up-front appointment setting between the family and the resident (23, 42, 44). In one case, facility staffs helped relatives know which was the best time to call the OA (awake and alert), and informed the relatives of the OA's health status: "*part of the time I [family member] get an update from her [staff member] on what is going on with regard to my husband*" (45). Staff members were also especially helpful in reassuring participants about the video calling technology (44).

Sometimes, the use of video calls was considered as another social activity and therefore was presented on regular communication supports of the institution (newsletter to the families) (25). In the case of the use of video calls for a game competition activity between the geriatric residences, the staff members were responsible for organizing the sessions and ensuring that the equipment worked properly (46).

Management

Issue: "What Management Problems and Opportunities are Attached to the Technology?" ID (G0008). The integration of a new technology into an elderly care institution often raised management issues. When facility staff was asked to implement video calls, understaffing and an already heavy workload were recurring organizational issues (25, 26, 46). Staff turnover and changing roles could also lead to loss of important information for the use of video calls, but also to a loss of skills (25, 46).

Culture

Issue: "How Is the Technology Accepted?" ID (G0010). The success of the integration of a new technology, activity, or intervention depends partly on its acceptance by facility staffs. In two studies reviewed, professionals showed no interest in ICT technologies and did not understand their usefulness in an OAs facility (26, 45). This lack of interest sometimes turned into an aversion to the technology, and despite training, professionals found it difficult to appropriate it, representing supplementary workload. A few professionals felt intimidated and considered video calls as a burden (25, 26). Some also doubted about their ability to learn how to use a new technology, which directly impacted their commitment (25).

However, when these professionals were involved as real actors in the video calls activities, and not only as assistants, the appropriation of the technology was better (46). In one study, organizing, participating, and observing the firsthand benefits of the technology increased professionals' commitment and desire to continue using it; especially since the intervention provided an opportunity for staff to *"link up [with other residences] and become more connected with each other to provide a more 'close knit' unit"* (46).

Cost and Economic Evaluation (ECO)

Resource Utilization

Issue: "How Does the Technology Modify the Need For Other Technologies and Use of Resources?" ID (D0023). The introduction of video calling technologies in an elderly care institution needs, at the very least, an investment in the basic video calling equipment (hardware, software). This kind of intervention may create other needs in terms of technology (Wi-Fi coverage in all rooms) but also resources (provision of user guides).

In this sense, beyond the help provided by staff members and researchers, most OAs expressed a need for additional and regular assistance in the use of video conferencing technologies (23, 42, 44, 45, 47), or individual training sessions: "*I would definitely need someone to help*" (39). In addition, the presence of technical problems almost always required the intervention of researchers (22, 24, 46). That is why Moyle et al. suggested to employ skilled staff to assist OAs with videoconferencing (47). However, a few staff members also requested additional guidance in the training provided (25). Finally, problems of accessibility of the technology required the use of additional tools, or ergonomic adaptations (e.g., sensor pens, support, volume control, larger screen) (22, 24–26, 41). Another solution could be to use a telepresence robot allowing the resident and their family to connect *via* a free-standing, wheel-based, videoconferencing system (47), or take advantage of the nurses station for this purpose, where tablets and help could be available for residents if needed (24).

Ethical Aspects (ETH)

Benefit-harm Balance

Issue: "What are the Benefits and Harms of the Technology For Relatives, Other Patients, Organizations, Commercial Entities, Society, Etc.?" ID (F0011). When implementing a new mode of remote communication involving the use of a technology, it is important to study the balance between the benefits and harms that it generates. First, there is the risk of reducing, or even completely replacing, traditional visits by relatives in the institution (27). Some families saw video calls as a way to reduce their guilt toward their institutionalized relatives or to reduce their sense of obligation to visit him or her, by substituting the visits with video calls (26).

However, no studies reported a decrease in the frequency of traditional visits after the introduction of video calls. On the contrary, several times, video calls were shown to increase social interactions between residents and their relatives, especially when the latter was unable to travel due to health reasons or geographical distance (22, 39, 40, 44).

Respect for Persons

Issue: "What are the Known and Estimated Benefits and Harms For Patients When Implementing or Not Implementing the Technology?" ID (F0010). The use of video calls raised the issue of privacy. Indeed, the facility staff members were often requested to ensure proper video calls functioning. This constant supervision raised the question of the privacy of exchanges between family members and OAs (26). In addition, the OAs expressed their concern about the loss of control over their image (47), but also about their perceived vulnerability to cyber-attacks (26, 47).

Autonomy

Issue 1: "Is the Technology Used for Individuals That are Especially Vulnerable?" ID (F0005). Some studies included OAs living with dementia or other advanced cognitive disorders (26, 44–46). Some of them expressed confusion and anxiety when the video calling technology was introduced in their room, causing agitation. However, these negative reactions seemed to decrease when the OAs recognized their relatives on the technology's screen (25). In some cases, OAs with dementia did not remember the conversations held during video calls (26). However, in another study, OAs with dementia could remember details of the conversation, the interlocutors, but not having used video calling technology to talk to them (46).

Justice and Equity

Issue: "Are There Factors That Could Prevent a Group or Person From Gaining Access to the Technology?" ID (H0012). Some factors may prevent some OAs living in geriatric institutions from taking advantage of or even using video calls. In a few studies, staff members decided which OAs were eligible (i.e., considered capable) for video calls intervention, without giving OAs the opportunity to try or to give their opinions on the video calling technology (24, 25, 47). In one study, researchers explained that this categorization could lead to discrimination. Indeed, researchers observed that some OAs with some cognitive or sensory deficits were naturally excluded, considered unable to use or benefit from the intervention (e.g., non-verbal OAs) (25).

Patients and Social Aspects (SOC)

Social Group Aspects

Issue: "Are There Factors That Could Prevent a Group or Person From Gaining Access to the Technology?" ID (H0012). Many factors limited access to technology for all facility residents, or only for a group of vulnerable OAs. Their self-perception, their abilities, but also the complexity of the tool are limiting factors to video calls use. Some OAs expressed insecurity about the image they projected of themselves through the use of video calls (25, 46), or had a low self-efficacy, simply not feeling capable of using such a technology: "*for me at 90, it is going to be difficult*" (47), "*Too old for VTC [Video telecommunication]*" (26), "*she would look 'silly' trying to use video calls*" (25). Another factor that could prevent the use of video calls was the attitude of OAs toward technologies in general. A negative attitude toward technologies (26), a feeling of discomfort when using technologies (24), a poor digital culture (44), and a low tolerance toward technical problems (22) were barriers to the use of video calls. On the contrary, a good tolerance toward technical problems was often associated with a good level of engagement with video calls (22). Some OAs who were not interested in this technology did not give any particular reason to explain their choice (25, 27, 45).

Some OAs did not dare ask their relatives to participate, thinking that they would be too busy to do so anyway (22, 24). The family, in fact, as an actor in the implementation of video calls, conditioned its use most of the time. Thus, an OA with relatives lacking involvement would generally not participate or would drop out of the video call study. A limited implication of the family (23, 25) could be explained by the lack of technical skills (22, 25–27), the difficulty of access to the necessary tools (25–27), the lack of motivation and interest in the technology (22, 26), their limited availability (22, 25–27), a poor relationship with their relative (26), preconceptions

about the institutionalized person's ability to use the device (e.g., thinking that it would be too difficult for the OA to use such a technology) (25, 27), their dependence on facility staff to make calls (45), or their difficulties in making an appointment to call the OA (if they were not in the same time zone for example) (24). A family that was very present and regularly visited the OA also limited the use of video calls (i.e., low usefulness) (22, 27, 42).

Patient's Perspectives

Issue 1: "What Expectations and Wishes Do Patients Have With Regard to the Technology and What Do They Expect to Gain From the Technology?" ID (H0100). No study mentioned the expectations and wishes of OAs toward video conferencing technologies. They only evaluated their opinions during or after the interventions.

Issue 2: "How Do Patients Perceive the Technology Under Assessment?" ID (H0006). Several OAs considered video calls as a way of reconnecting with their family and renewing social ties (23, 25, 26, 47). This new experience (26) was evaluated as positive (25, 39, 47), having the potential to improve the quality of conversations with the family: "*it would feel like you were talking to the caller in-person and be more in contact*" (39). However, video conferencing was still considered the second-best option compared to in-person visits (26, 42). However, some OAs perceived the technology used as intimidating (24), complicated (25), and even dangerous in the case of cyber-attacks (26, 47).

Legal Aspects (LEG)

Aspects related to rules and regulations were not described in the publications reviewed.

DISCUSSION

The purpose of this research was to compile and review existing literature on video calls involving OAs in elderly care institutions from January 2000 to June 2021. Our search identified 15 studies, with a wide variety of intervention designs, study settings, and sample characteristics. The objective of this review was first to identify barriers, enablers, as well as solutions to the implementation of video calls in elderly care institutions using a multidimensional perspective, and second to explore the benefits of this service on the maintenance of OAs' social interactions. The EUnetHTA multidimensional framework (35) was used for guiding the analysis of publications. In this section, we discuss main facilitators, barriers and solutions identified for the implementation of video calls in geriatric settings and provide suggestions for future work. **Supplementary Table 3** summarizes enablers, barriers and inferred solutions.

Factors That Facilitate the Use and Adoption of Video Calls Interventions

Feasibility

Among the enablers of video calls interventions, it is important to underline that most of the authors showed the feasibility of the implementation of video calls in elderly care institutions. Evidence of this is that, at the end of each study, despite the barriers encountered (technical difficulties, need to be helped by professionals during the video calls), several OAs continued to benefit from video calls with their relatives. This can be explained by the fact that the participants found the benefits more important than the obstacles.

It is interesting to note that videophones did not elicit strong rejection from residents, as their ergonomics were similar to those of traditional landline telephones, which are widely used among this population. Furthermore, using video calls instead of telephone calls was more a change in the means of communication than a change in the habits of communication for the OAs. Video calls interventions were also considered feasible because devices employed were available for a general public and were also low cost.

Usefulness

As emphasized by all the studies in this review, video calls are useful since they enable OAs to have more meaningful remote communication (both audio and visual) with their relatives, especially those who live far away. Furthermore, the several COVID-19 confinements particularly highlighted the usefulness of video calls, as reported in two studies (44, 46). Thus, despite some reluctance of institutionalized OAs toward those technologies, they seemed to prefer video calls over traditional telephone calls to communicate with their relatives (44).

Motivation

Another strong enabler to video calls use was OAs' interest in video calls service. However, as their environment played a central role, OA's motivation was closely related to family and staff members' motivation itself. Indeed, those two stakeholders played an active role in facilitating the use of video calling technology by OAs. However, family and staff members' implication and interest on the service mostly depended on their capacity of using it, on their tolerance of technical and operating difficulties (14), as well as on their attitudes toward video calls. Most of the time, their positive attitude would reflect on the resident, and thus would encourage video calling technology usage (39). For example, Luijkx et al. (50) showed that OAs easily adopted the enthusiasm of their grandchildren for technology (50). Moreover, the proactivity of family and staff members through stimulations and availability of technical support also participated in video calls use by OAs.

Video Calls as a Form of Psychosocial Intervention to Support Socialization in OAs

The secondary objective of this work was to explore the impact of video call interventions on social interactions. The results of the present study showed that nine articles out of 15 that were selected identified a positive impact of video calls on the maintenance of social ties, either in terms of improving the quality of interactions and social support between the resident and his/her relatives, or in terms of social isolation and loneliness. These results are in line with those shown by Schuster et al. (30) in a previous work dedicated to video calls for cognitively intact

OAs (30). In a review of literature focused on interventions to combat loneliness in OAs living in long-term care, Quan et al. (3) also observed a reduction of loneliness with video conferencing in nursing home residents (3). They categorized video conferencing with family members as a "social facilitation interventions", according to a classification proposed by Gardiner et al. (51). According to these authors, the primary purpose of this kind of intervention is to facilitate social interaction with peers, or others who may be lonely: "*social facilitation interventions generally presume a degree of reciprocity, and strive to provide mutual benefits to all participants involved*" (51). Such interventions could help OAs to maintain social relationships with family and friends, especially when they are not able to do physical exercise or travel anymore (52). Indeed, residents suffering from a reduction of mobility are at risk of having fewer social relationships and feeling lonely. Quan et al. (3) underlined that the most successful interventions for these OAs were those that did not entail physical activity or mobility (3).

However, although results that evaluate the efficacy of these interventions are promising, there are still few randomized studies on the implementation of video calls in institutions, and most of them involve small samples (30, 53). Thus, no significant evidence was found to support the effectiveness of video calls on reducing loneliness in older adults (53, 54). Future randomized trial with large samples would be necessary to confirm the benefits of video calls interventions involving OAs in geriatric institutions. It is interesting to note that those benefits could be potentiated if video calls sessions with relatives were complemented either by entertaining activities performed individually (41) or in group while videoconferencing with other residents from other institutions (46). Thus, even though "*there is no one-size-fits-all approach to addressing loneliness or social isolation*" [(54), p. 2], future studies should provide concrete guidance for interventions to be more effective with this population.

Identified Barriers to the Implementation of Video Calls Interventions and Potential Solutions

The implementation of video calls in institutions comes up against several technological, human, organizational and ethical obstacles.

Technological Barriers and Possible Solutions

This narrative review has included a broad span of technologies (**Supplementary Table 2**), from videophones to tablets or smartphones. However, only three different software programs were used (e.g., Skype, MSN and Line), and no mention was made of WhatsApp or Zoom. The Skype software program was largely used because it is broadly available for all platforms (26) and free of charge (24, 25).

A first technological barrier identified in the analysis was the recurrence of technical problems encountered, such as an audio lag or a call disruption, which affected greatly video calls use. The development and generalization of new technologies and Wi-Fi seem to have solved most of those problems. However, the evolution of digital tools and services has brought new ergonomic issues, which also impact their usability and accessibility. In the selected articles, OAs who participated in video calls had to use computer, tablet or smartphone that required tactile interaction, and thus, more complex interfaces. OAs generally found difficult to use the touch screen, but also found the devices too heavy. However, the authors made no mention of usability issues caused by the software programs interfaces.

A possible solution to enhance the first experience of the video calling technology by OAs could be to identify those ergonomic and technical problems, early in the intervention, by conducting user tests with OAs. These tests would help to make the video calling technology more accessible to older users, either by providing ergonomic adaptations if needed (e.g., sensor pens, tablet support), or by choosing technology more tailored to OAs' needs such as a mobile telepresence robot (47), or a TV (25).

Apart from videophones, most of the OAs seemed to need training in the basic knowledge of video calling technologies. These training programs need to be adapted to OAs' cognitive capacities. Quillion-Dupré (55) created an adapted training program for OAs to use a tablet-based digital agenda. She designed an errorless training with spaced retrieval, a method proven to be more efficient than classical techniques such as trial-and-error learning, especially with OAs with memory impairment (56, 57). Czaja and Sharit (58) provided several recommendations on good practices for designing training that is appropriate for OAs. For a training program to be useful and effective, the form (individual/collective; face-to-face/online; with/without manual; paper/digital manual; formal/informal), the length of the program, the frequency and duration of the training sessions, the location in which the training takes place (home, association...), the pace within the training sessions (set by the instructor/by the learner), etc., should be considered.

However, although training may resolve several usage problems, some OAs may still face usability issues. In this case, additional support by skilled staff members during video calls sessions should be provided to ensure proper use of the video calling technology.

Human-related Barriers and Possible Solutions

The implementation of video calls in geriatric institutions requires considering OAs' socialization needs, as they already have their habits with telephone calls or in-person visits. Thus, OAs could be reluctant to use an additional communication technology. Moreover, OAs' physical, cognitive and sensory disorders may increase their fatigability, which in turn could impact their perceived vulnerability, their self-esteem and their self-efficacy toward video calling technology. Combined with OAs' lack of experience and negative attitude toward technology, those factors may affect video calls use.

Families' motivation was identified as an enabler in video calls use. However, when family members are more reluctant about video calls, or have a low tolerance for operating and technical difficulties, the resident/family member dyad tends to have a low potential of video calls use (22). Mickus and Luz (22) suggest to this end, some criteria to determine the dyad's potential of effectively using video calls services (i.e., dyad with high, contingent, low, or no potential).

A possible solution to better take into account OAs' vulnerabilities and disorders could be to embed video calls use into regular activities such as meals, or entertainments. This solution has the advantage of not adding extra fatigue to the day, as well as to 'dress-up' the video calling technology (38), allowing a more progressive familiarization to the video calls services.

In addition, it could be interesting to add a purpose to those video calls sessions [e.g., asking OAs to teach their language to foreign people using the video calls services (43)]. The feeling of being useful during the video call seemed to be rewarding for these OAs and motivated them to overcome potential difficulties associated with the video calling technology.

Finally, training and regular support by staff members appeared to be crucial for OAs to understand the video calling technology, as well as to reassure them about their own capacity in using it. In order to include families more easily into video calls use, it could be interesting to provide a similar kind of training and technical support to family members in need of assistance.

Organizational Barriers and Possible Solutions

As stated in the literature review by Schuster and Hunter (30), professionals actively contributed to the use of ICT in elderly care institutions (30). Seven authors out of 15 studies emphasized the role of assistance or troubleshooting by facility staff.

However, the shortage of personnel, the frequent turnover, and their high workload were major obstacles to the implementation of video calls in geriatric settings. Indeed, video calls implied additional tasks such as scheduling appointments, or providing technical support to OAs or even to family members. This supplementary workload, together with staff members' lack of experience and low self-efficacy could negatively impact their motivation for video calls sessions.

That is why, in order to counter those barriers, it is important to study the capacity of staff members to use video calls considering their current working conditions (30). Providing staff members with training sessions appeared to be critical before video calls implementation. Once facility staff was familiarized with the video calls systems, they could then provide assistance for OAs and family members. Thus, considering the team configuration required for the implementation of video calls in geriatric contexts, it would be more appropriate to speak of a triad (i.e., resident/family member/facility staff) than of a dyad (i.e., resident/family member). It would be indeed the triad that determines the potential of use of video calls in geriatric institutions. This finding echoes a dimension that has been discussed in detail in the literature and promoted in "person-centered" approaches to dementia care. Within these approaches, the underlying idea is that care is provided within "dementia care triads" involving the OA with dementia, the informal carer and the health or social care professional (59).

Finally, actively involving staff members into video calls activities could increase their motivation to use this service. In the study by Zamir et al. (46), video calls were integrated into an inter-residential quiz competition, where professionals were major actors. Thus, these professionals welcomed this intervention and were motivated to participate, a feeling that did not seem to be shared by those who only managed technically the calls between the OAs and their families. It might be interesting to test the benefit of integrating video calls in other occupational or therapeutic activities in a randomized study.

Ethical Questions

As stated above, video calls use could be hindered by numerous barriers, which were sometimes difficult to overcome. First, there is the question of providing equal and non-discriminatory access to the service.

In some cases, family members or professionals assumed *a priori* that the OA, because of physical and/or cognitive limitations, would be unable to use the technology, without giving him/her the opportunity to try it out, resulting in the exclusion of some people from the intervention. For instance, in one institution, residents with hearing impairments were not recruited by staff members to take part in the video call activity, and thus, missed the opportunity to try and potentially benefit from the intervention (25). A more inclusive and facilitative attitude was observed in other studies, for instance, in another care home, a non-verbal OA had the opportunity to enjoy video calls using lip-reading and sign language. For future works, in order to provide an equal access to video calling technology, it could be interesting to propose it to residents who want to take the opportunity to try the service, regardless of their limitations and, during the tests, to identify the types of adaptations of the activity required to make it accessible to each individual.

A second ethical theme relates to the respect of privacy and autonomy. Indeed, some OAs expressed concerns about video calls systems, evoking security issues [such as having their identity stolen by hackers (26, 47)], or the lack of control over the technology [less control of their image (47)]. To reassure OAs about the technology, accessible information should be provided on the way that video calls services work regarding the respect of privacy and safety, during training and informational programs offered to OAs and to the other actors.

A third theme concerns the balance between benefits and risks of video calls for vulnerable persons, such as OAs with dementia. From the data analyzed, it is not certain that the concept of video calls was well understood for these users. Indeed, several residents suffering from dementia seemed to remember details of the conversation, the interlocutors, but not the context of the exchanges (46). Cognitive deficits may challenge the ability of these individuals to understand the concept of video calls, i.e., talking to a person who is not physically present. Some OAs with dementia have expressed confusion and anxiety when the video calling technology was introduced into their room (25). In some cases, this misunderstanding and confusion introduced by the technology were avoided by the presence of a traditional telephone handset (25). As this handset was the very symbol of remote communication, its presence allowed OAs to understand the purpose of the technology and thus, to use it with confidence. Moreover, explaining and reminding the purpose of the activity before each session could also help the OA to understand the situation. Teams implementing this kind of intervention should take the necessary measures to ensure OAs' satisfaction and pleasure during those sessions, and to make sure that they do not suffer from side-effects (anxiety, confusion). It could be useful

to implement regular staff meetings that enables members to exchange about their experiences of video calls with OAs and family members. Staff members could also discuss the benefits-risks balance for each OA taking part in this activity.

Finally, the risk of substitution of physical visits by video calls was another ethical theme identified in the analysis. This risk was reported by family members (26) as well as OAs (45). Several works have discussed how this kind of technology-based care-related interventions should promote and enhance human contact rather than threaten it (60–62). Regarding this issue, a solution suggested is that professionals who administer video calls activities monitor the balance between the modalities of social contact that are offered to older adults in an institution. Broadly, it is recommended to include these ethical considerations in the implementation and impact assessments of video call technologies in care contexts.

Contributions of the Study

One of the main contributions of this work was to conduct a multidimensional qualitative analysis of the literature on the use of video calls in geriatric institutions using the framework provided by the EUnetHTA Core model, version 3.0 (35). This methodology allowed us to examine the factors involved in the implementation of video calls with institutionalized OAs from multiple perspectives, and in a comprehensive way.

Moreover, in the selected articles from the literature review, video calls use has encountered several barriers at different steps of its implementation in geriatric institutions. This analysis helped us to suggest concrete recommendations for each stage of the process: the preparation, the conduct of sessions, and the evaluation of video calls use in geriatric settings. These suggestions are presented in the next subsection.

Authors' Recommendations for the Implementation of Video Calls Interventions in Geriatric Settings

Planning Stage

- Discuss with staff members how video calls interventions could help meet residents' social needs and how could this intervention be integrated into the facility's activity programs.

- Allow staff members involved in the implementation of the intervention an adequate time for planning and information.

- Identify one or two project referents, among the facility staff members, that undertake the coordination of the interventions and can provide the leadership necessary for successful implementation.

- Carefully examine available technological solutions available for video calls and choose the one that seems to best meet the needs of residents, family members, and staff in terms of accessibility, ease of installation and use, costs, training needs, data security and privacy issues, technical assistance needs, and sustainability.

- Identify the residents and families interested in the intervention, or who could potentially benefit from it, and present the project to them in a clear and precise manner (e.g., technology, modalities).

- Define an individual plan of socializing activities for each resident who will benefit from video calls, ensuring a balance between remote and direct social contacts.

- Set up a training program for the residents who will participate in the video call activity that is adapted to their needs and abilities. This may be the opportunity to conduct some usability tests and define the necessary adaptations to ensure the accessibility of the activity (technical or human).

- Offer to professionals and members of the resident's family or friends, interested in the activity, specific training on the use of the device. The availability of pedagogical material adapted to this objective (e.g., tutorial) can help to improve the understanding of the use of the system and its adoption.

- Define a mode of use of video calls that will allow for the privacy of the participants (even if a professional must be present during the call).

- Define with the professionals who will manage the activity a strategy for the handling of technical problems that will allow, on the one hand a quick resolution, and on the other hand to calm and reassure the residents and their family members.

Conduct of Sessions

- Solicit family members and members of the resident's entourage interested in using the video calling device early enough to schedule an accurate time for the call.

- Respect the schedule that has been agreed upon for the video call with residents and their family members or friends to avoid frustrations or unrealistic expectations (e.g., wanting to use the service at any time when the professionals coordinating the activity or the device are not available).

- Before initiating a video calls session explain again how to use the device and how the session is going to run.

- Monitor the use of the system during the video call session to make the necessary technical or ergonomic adaptations (e.g., volume level, video viewing).

- Monitor resident's behavior during the video call to identify any signs of confusion or stress and adapt the activity accordingly.

Assessment

- Define a way of monitoring the activity at the individual and at the institution scale to identify the necessary modifications, whether at the technical, training or psychosocial impact level. A follow-up activity sheet can be used for this purpose.

- Include the video call activity in the team debriefings and evaluation sessions to allow professionals to discuss, on the one hand, about individual and organizational impacts of the intervention, and to define ways to improve the implementation of the device, on the other hand.

- Keep a regular check on the updates of the technologies and applications allowing the conduct of video calls in order to always have a stable, robust and secure system at disposal.

Limitations of the Study

In this review, the thematic analysis was based on the EUnetHTA Core Model® (35). Thus, data were coded and interpreted according to EUnetHTA domains, topics and issues, used

as a set of pre-defined codes to guide the process of data interrogation and organization. However, the use of this model for thematic coding was not straightforward as the different dimensions of the model intersect and complement each other. A proposition in the text of the original publication included in our analysis, which constituted our primary data, referred in many cases to multiple dimensions or topics of the model. Consequently, the coding was done using all the relevant categories from different dimensions, but the presentation in the results section required the proposition to appear within one or another dimension, whose pertinence was decided by consensus. The model certainly provides a very interesting guide for understanding the use and impact of health technologies, and for analyzing scientific publications in the field, but its application requires an important degree of discussion and consensus among researchers.

Another limitation encountered refers to the selection of publications for the review. First, only publications in English and French were selected. Second, it is also possible that studies that did not mention video calls or elderly care institutions in the key words or in the abstract were not included. Third, the literature review did not take into account the quality of the intervention, or the study described, since we gave priority to include as many relevant publications as possible. Thus, some factors that we know are important for the understanding of the interventions or for the appreciation of their impact were not considered in our analysis (e.g., inclusion of a control group, sample sizes, proper description of health status of participants). These aspects limit the generalizability of our results.

CONCLUSION

The isolation and loneliness of OAs in institutions are a problem that has been particularly discussed lately with the successive confinements and restrictions due to the COVID-19 epidemic. Video calls have been one of the solutions proposed by several geriatric institutions to maintain the social link between residents and their families. This literature review has shown that this technology can help connect OAs with their loved ones who are unable to travel. Generally speaking, when the family and the resident perceive the usefulness of video calls, such as having richer exchanges, this service reduces the feeling of loneliness in the OAs and improves the quality of social interactions within the family.

However, the level of acceptance of video calls by the residents, their families and the facility staff varies according to the studies. Various organizational, human-related, ethical and technological barriers and proposed solutions were also identified. Future research must better take into account the family and the facility staff perspectives and needs in the implementation and the study of the acceptance of video calls in institutions. In the future, health economics, organizational, ethical and legal aspects should be better described and addressed. Finally, we highlight the importance of conducting small pilot tests before the implementation of video call services in geriatric institutions that can be helpful to identify technical, human-related, organizational or ethical requirements at the institutional and the individual level.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

BN, A-SR, and MP: conceptualization and methodology, writing—original draft preparation, and writing—review and editing. BN: formal analysis and investigation and project administration. All authors have read and agreed to the published version of the manuscript.

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Social Isolation, Cognitive Function, and Depression Among Chinese Older Adults: Examining Internet Use as a Predictor and a Moderator

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Objectives: Despite the theoretical and practical interest in Internet use among older adults, evidence examining the impacts of Internet use on late-in-life health is limited. This study examines how Internet use affects depression and cognitive function in older adults and investigates if Internet use moderates the relationship between social isolation and depression/cognitive function.

Method: We performed regression analyses using data came from the second wave of the China Longitudinal Aging Social Survey of 2016. Our final sample featured 8,835 older adults.

Results: The results show 11.4% of Chinese older adults often used the Internet to engage in at least one activity. Internet use was negatively associated with depression, but it was positively related to cognitive function. Socially isolated older adults were more likely to have more depressive symptoms and higher level of cognitive function. There was also an interaction effect between Internet use and social isolation on depression/cognitive function. The negative effect of social isolation was stronger for older adults who used the Internet less. The moderating effect of Internet use was significant for both males and females. However, among those who used the Internet more, the depression levels of socially isolated male participants were much lower than female participants.

Conclusions: Our results reveal the importance of considering Internet use in buffering the negative effects of social isolation and the associated health burdens for aging populations. Recommendations for service practice and future research are discussed.

Keywords: Internet use, social isolation, older adults, cognitive function, depression

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INTRODUCTION

Aging is associated with several stressful life transitions (such as spousal bereavement, retirement, and residential relocation) that lead to an increased risk of shrinking social networks among older adults (1). Such status, defined as social isolation, generally refers to the lack of network size, network diversity, and frequency of

contact (2). Accordingly, the unprecedented population aging, coupled with the anticipated loss of intimate relationships and changes in health and social status among older people, suggests that late-life social isolation and associated health problems are emerging as significant public health concerns (3, 4) now exacerbated by the COVID-19 pandemic. Particularly, there is growing concern regarding the effects of social isolation on cognitive function and depression among older adults, in light of healthy aging being pivotal to alleviating burdens of an aging society (5–7). Indeed, numerous studies in Western countries have demonstrated that social isolation puts older people at great risk of depression and cognitive impairment (8, 9); yet studies seldom investigated possible modifying factors in this linkage. Guided by the stress-coping framework, the current study investigated Internet use as a potential moderator and whether it might buffer the negative effects of social isolation on increased depression and cognitive impairment among older adults.

Researchers have proposed the opportunities and benefits the Internet could bring to socially isolated individuals as a promising solution to those challenges, including promoting social connections over remote distances, facilitating online information seeking (e.g., health-related issues), and enhancing competence and autonomy through learning new Internet skills (1, 10, 11). Although previous studies have attempted to identify the association between Internet use and older adults' well-being at an emotional and cognitive level, existing evidence remains equivocal (12, 13). Moreover, most related studies have been conducted in Western countries, with only a few attempts among the Chinese aging population. Besides, a strong recommendation to explore cultural diversity in this topic has already been proposed by researchers, because differences across racial and ethnic groups surrounding Internet use have been documented in the literature (14). For most Chinese older adults, they had entered middle or old age when digital technologies first appeared as a novelty and they began to learn how to use the Internet. Thus, with its late popularization of the Internet amid challenging technical difficulties for older adults, China offers a unique context to advance the global understanding of Internet use.

Given these considerations, including challenges for socially isolated older adults, the potential benefits of Internet use, and the poor computer literacy of Chinese older adults, with a national probability sample of older adults in China, this study aimed to: (a) examine Internet use as a predictor of depression and cognitive function; and (b) investigate Internet use as a moderator in the relationship between social isolation and depression and cognitive function.

Social Isolation and Internet Use Among Chinese Older Adults

Although Chinese culture has long been recognized as collectivistic or family centered, it has been documented that the traditional family-based model of social networks has gradually weakened for aging parents, partly resulting from the massive internal migration in China (15). According to the China Family Development Report released by the National Health and Family Planning Commission Family Division (16), the "empty-nest elders," as labeled in the Chinese context and referring to older adults who reside alone or only with their spouse while their children live far away from home (for work or other reasons), account for nearly 50% of older adults, of whom 10% live alone and 41.9% live only with their spouses. Data on the prevalence of social isolation among older adults in the Chinese context remains rare; yet arguably, in view of the "empty nest" phenomenon, socially isolated older adults are very likely to account for a surprisingly high proportion of the population. Moreover, along with the limited socialization after retirement in China and the cultural norm emphasizing interpersonal relationships (17), it is justified to assume that social isolation might provoke more profound adverse effects among Chinese older adults, including higher levels of depression and cognitive impairment, which also makes it urgent to explore corresponding interventions.

As indicated in preceding reviews on the potential benefits of Internet use, older adults in China are increasingly using the Internet with the rapid expansion and the availability of digital technology. In Western countries, Internet use has become more pervasive and integral to the day-to-day functioning of older adults' lives (14, 18). Similarly, in China, an increasing number of older adults have begun to use the Internet. According to the 47th Statistical Report on Internet Development, China had 989 million Internet users as of December 2020, with the percentage of users aged 50 and above rising from 16.9% in March 2020 to 26.3% in December (19). However, not until the 1990s did the Internet and other information technologies rapidly develop in China; Chinese older adults have been called "digital refugees" who generally are unfamiliar with new technologies and less able to use the Internet (17). Thus, unlike their Western counterparts, Chinese older adults' poor computer literacy might provoke more challenging technical difficulties and thereby, increase their negative emotions in the process of Internet use.

Empirical Evidence on Internet Use and Older Adults' Well-Being

Despite the theoretical and practical interest in Internet use among older adults, researchers have pointed out that the relationship between Internet use and older adults' well-being has not yet been adequately explored and is not well-understood (20).

First, much research has attempted to examine the Internet's association with depression in older adults; yet the findings were mixed (12, 13). For example, in a study of 591 American older adults (50+), Chopik (12) found five Internet activities (i.e., using e-mail, social networking sites, online video/phone calls, online chatting/instant messaging, using a smartphone) were related to fewer depressive symptoms. However, a cross-sectional study exploring the phenomenon of Facebook Depression among 529 individuals aged 18–70+ years demonstrated that older participants were more resilient to the negative effects of Facebook use, especially compared to the younger cohorts (21). Second, despite the strong implications of increased incidence of cognitive decline and disorders in later life and their strong impacts on public health, less is known about the role of Internet use in late-life cognition (22). Also, as

Kamin and Lang (23) suggested, there was limited empirical evidence supporting the positive relationship between Internet use and older adults' cognitive function, and most of them were intervention studies with small samples, which calls for more research with a larger sample or longitudinal design to enhance the result's generalizability.

Echoing the aforementioned equivocal findings, many researchers also pointed out the dark side of Internet use has been often overlooked. For example, Ahn and Shin (24) postulated that individuals might spend a substantial amount of time online, even sacrificing time for other valuable activities (e.g., face-to-face communication with family members), thereby reducing meaningful human contact and paradoxically increasing psychological distress. Sum et al. (25) demonstrated that online communication with acquaintances could alleviate older adults' distress, but prolonged Internet use was positively associated with negative mental outcomes. Salovaara et al. (26) highlighted the negative impacts of technical difficulties, that is, it is the process of learning how to use the new and confusing electronic device that might trigger older adults' negative emotions, including anxiety and low self-efficacy. Therefore, one focus of this study was to expand our understanding of the role of Internet use among older adults with a nationally representative sample.

Stress-Coping Framework and the Moderator Hypothesis

The stress-coping framework has greatly contributed to research on the impacts of stressors on individuals' well-being (27) and therefore, at what level a stressful status like social isolation exerts negative effects would be influenced by older adults' coping resources (namely, a moderator). Theoretically, there is considerable reason for the current study to examine Internet use as a potential moderator in the linkage between social isolation and depression and cognitive function.

As Hofer et al. (10) argued, Internet use could be viewed as a valuable resource for older adults to manage loss, especially for those who face more mobility or activity limitations or frailty. Importantly, it has been reported that social networking was the top usage for Internet users in many countries (21). Scholars have suggested Internet could enable older adults to overcome space limitations, regardless of their frail physical conditions and living locations, thereby allowing them to better connect with the outside world at any time (28). Thus, the Internet could be a tool that increases social support for, improves the social engagement of, and benefits older adults (17, 29, 30). In such cases, it is possible that older adults' pre-existing habits of using the Internet would buffer the effects of social isolation on increasing older adults' depression levels. Meanwhile, according to the information processing model, the Internet has long been recognized as a cultural tool that influences cognitive processes and an environmental stimulus that contributes to the formation of specific cognitive architecture (31). Thus, for socially isolated older adults, it is possible Internet use might mitigate the negative effects of social isolation at the cognitive level. Additionally, though researchers have sought to determine how Internet use affects late-life health outcomes through different pathways (1, 23, 29, 32), few studies have examined such a moderating hypothesis of Internet use. As an exception, in a study of 6,443 community-dwelling older adults (65 or older), Elliot et al. (14) found that the level of technology use moderated the effects of two variables (limitations in ADLs and ill health) on depressive symptoms among participants.

However, considering the aforementioned possible negative impacts of Internet use, there is an imperative need to test the moderator hypothesis of this study; that is, to examine if Internet use acts as a moderator to buffer the negative effects of social isolation on older adults.

Present Study

Based on the literature review and research gaps described previously, the current study aimed to address two specific research questions using a national probability sample of older adults in China: (1) Is there a relationship between Internet use and depression and cognitive function? (2) Does Internet use moderate the relationship between Internet use and depression and cognitive function?

Moreover, scholars also have suggested that gender differences in the effects of older people's Internet use on their well-being remain underexplored (20, 33), despite evidence that older women and men often use the Internet for different purposes or in different patterns. For instance, older women tend to use the Internet more for communicative purposes, whereas older men are more likely to use the Internet for leisure activities (34). Meanwhile, Chinese studies have also indicated gender as an important predictor of the dependent variables in this study (35, 36). Taken together, the present study further tested the moderating effects based on female and male groups. Thus, from these research purposes and questions, five hypotheses were developed:

H1: Older adults using the Internet more are less likely to have higher depression levels.

H2: Older adults using the Internet more are more likely to have higher levels of cognitive function.

H3: Older adults who are more socially isolated are more likely to have higher depression levels, and Internet use buffers the positive relationship between social isolation and depression.

H4: Older adults who are more socially isolated are less likely to have higher levels of cognitive function, and Internet use strengthens the negative relationship between social isolation and cognitive function.

H5: The moderation model in this study is applicable to both male and female participants.

METHODS

Data

The China Longitudinal Aging Social Survey (CLASS) is a nationally representative and longitudinal survey of Chinese aged 60 and above. The baseline survey and the recent follow-up survey of the CLASS were fielded in 2014 and 2016, respectively. The 2016 CLASS was the first to include a set of variables

measuring Internet use among older adults, so this research used the follow-up data from 2016.

The study sample of CLASS was randomly chosen with a three-stage probability proportionate to size sampling method. 134 counties/districts were selected from a sampling frame containing all county-level units in the first stage. In the second stage, 462 villages/communities were drawn at random with the ratio of urban-to-rural population size set at 6:4. In the third stage, older adult per household was randomly selected based on a mapping-and-listing sampling method. The final sample of the baseline survey involved 11,511 respondents. The 2016 CLASS survey successfully tracked 6,603 respondents, with a 57.4% follow-up rate. After supplementing the sample with 4,892 respondents, there were 11,471 sample respondents. After variable screening and data cleaning, the final sample size of this study's moderating model was 8,835 (**Figure 1**).

Measurements

Internet Use

In the 2016 CLASS questionnaire, participants were asked the following question: "Do you often participate in the activities listed below on the Internet?" The listed items were as follows: "reading current news," "watching videos," "chatting with others," "shopping," "playing games" and "investing in stocks." Each answer was either "*no*" (=0) or "*yes*" (=1). This study used the sum scores of these six Internet activities as an indicator of Internet use among older adults. Overall scores ranged from 0 to 6. Higher scores represent higher levels of Internet use. Cronbach's alpha for Internet use was 0.79.

Social Isolation

In the CLASS questionnaire, the measure of social isolation was adapted from the Lubben Social Network Scale (37), then validated in Chinese older adults (38). Participants were asked two sets of questions about family and friendship ties, with three items in each set. The questions included: "the number of relatives/friends see or hear from at least once a month," "the number of relatives/friends they feel able to call for help," and "the number of relatives/friends they feel at ease to talk about private matters." Answers were measured on a 6-point Likert-type scale, ranging from 1 (*5 to 8 persons*) to 6 (*no one*). The scores of the six items were summed up and placed on a scale of 6–36. Higher scores indicate higher levels of social isolation. Cronbach's alpha for social isolation was 0.88.

Depressive Symptoms

The measure of depressive symptoms was adapted from the Center for Epidemiologic Studies Depression Scale (39), and validated in Chinese older adults (40). Participants were asked about the frequency of depressive symptoms occurring during the past week on a 3-point scale ranging from "*rarely*" (=1), "*sometimes*" (=2), and "*most of the time*" (=3). Sample items

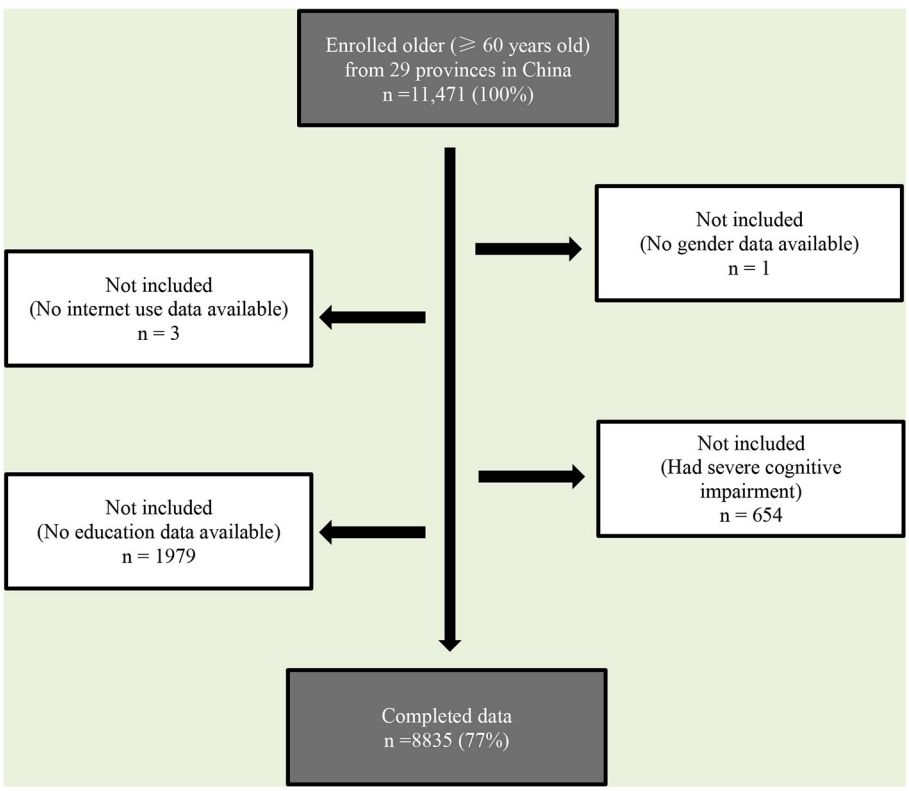

FIGURE 1 | Sample selection flowchart.

included: "Do you feel upset during in the past week?" and "Do you have sleeping problems in the past week?" After three positive items were reverse recorded, the scores of the nine items were summed up and placed on a scale of 9–27. Higher scores indicate higher levels of depression. Cronbach's alpha for depressive symptoms was 0.78.

Cognitive Function

The measure of cognitive function was adapted from the abbreviated Short Portable Mental Status Questionnaire (41), and validated for screening for cognitive impairment in Chinese older adults (42). In the CLASS questionnaire, participants' correct answers to listed questions were coded 1, whereas errors were coded 0. Sample items included: "What are the day, month, and year," "Where are you located now," and "Can you count backward from 100 by 7's?." The scores of the eight items were summed up and scored on a scale of 0–16. Higher scores indicate higher levels of cognitive function. Cronbach's alpha for cognitive function was 0.85.

Control Variables

Sociodemographic variables, including gender (1 = *female*), age, marital status (1 = *married*), education, ethnicity group (1 = *Han majority*), religious affiliation (1 = *having a religious affiliation*), living status (1 = *living alone*), region (1 = *urban*), personal pension level, number of children, and functional health, were included as control variables. Personal pension level was assessed by a 6-point scale ranging from 1 (*other social endowment insurance*) to 6 (*basic old-age pension system for civil servants*). It corresponded to the schemes of China's pension coverage identified by previous research (43). A higher score indicates a higher level of financial self-sufficiency. This study also assessed functional status using the 6-item activities of daily living (ADL) scale (44) and the 8-item instrumental activities of daily living (IADL) scale (45). Each ADL and IADL item was rated on a 3-point scale ranging from "*on my own*" (=1), "*with help*" (=2), and "*unable*" (=3). Higher final scores indicate higher levels of functional limitations. Cronbach's alphas of ADL and IADL were 0.87 and 0.89, respectively.

Analysis Plan

Hierarchical regression analysis was applied to investigate Internet use and other related factors in relation to the dependent variables (cognitive function and depression) and to explore the moderating role of Internet use on the association of the independent variable (social isolation) with the dependent variables (46). We estimated four models to predict cognitive function and depression, respectively. In each set of regression analyses, we entered control variables in Step 1 of the model, social isolation in Step 2, Internet use in Step 3, and an interaction term (e.g., social isolation × Internet use) in Step 4. To avoid multicollinearity, we mean centered the moderating variable before creating the interaction term. And, to identify the possible primary and interaction effects of social isolation and Internet use on cognitive function and depression, we examined changes in R^2 from Steps 2–4. The hypothesis of the moderating effect of Internet use would be supported if the interaction was significant (46), and simple slope analysis was conducted to visualize the interaction term. All analyses were conducted in SPSS Statistics 22.

RESULTS

Descriptive Statistics

The mean age of the participants was 69.69 years ($SD = 7.29$), with a range of 60 to 106. 51.8% of the participants were male, 72.8 % were married, 23.4 reported illiteracy, 7.3% had an ethnic minority background, and 9.5% had a religious affiliation. The average score for Internet use was 0.25 ($SD = 0.83$), and 7,912 participants (89.6%) reported they didn't often use the Internet for any of these six purposes. Reading current news (9.0%) was the most common activity for older adults to use the Internet, followed by chatting with others (6.9%) and watching videos (4.4%). The prevalence rates of playing games, shopping, and investing in stocks were 2.8, 1.3, and 0.9%, respectively. The socio-demographic characteristics of the participants are summarized in **Table 1**.

Moderating Effects

Table 2 reported the interaction effects of Internet use with social isolation on cognitive function. Model 1 included all sociodemographic variables and depressive symptoms as control variables. The results show older adults who were male, who were younger, who were married, or who were Han majority were more likely to have better cognitive function. Urban residence, education, and personal pension level were positively related to the level of cognitive function while having a religious affiliation, ADL, IADL, and depressive symptoms were negatively related to it. Living status and the number of children were not associated with cognitive function. Model 2 further included social isolation in the model and showed it was negatively associated with cognitive function ($\beta = -0.06$, $p < 0.001$). Model 3 included Internet use and demonstrated it was positively related to cognitive function ($\beta = 0.05$, $p < 0.001$). Model 4 showed the interaction effect of Internet use and social isolation was significantly positive ($\beta = 0.20$, $p < 0.001$). That is, the result indicates a moderating effect of Internet use in the relationship between social isolation and cognitive function, as visualized in **Figure 2**. The association between social isolation and cognitive function differed according to the level of Internet use. The strength of the negative relationship between social isolation and cognitive function was stronger for older adults who have a lower level of Internet use.

Table 3 provided the results of testing moderating effects of Internet use on the association between social isolation and depression. Similarly, Model 1 included all sociodemographic variables and cognitive function as control variables. The results indicate older adults who were female, who were married, or who were Ethnic minority were less likely to have a high level of depression. Urban residence, education, personal pension level, and cognitive function were negatively related to the level of depression, while living alone status, the number of children, ADL, and IADL were positively related to it. Age and religious affiliation were not associated with depressive symptoms. Model

TABLE 1 | Descriptive statistics of analytic variables ($N = 8,835$).

	n or *M*	% or *SD*
Gender		
Female	4,255	48.2
Male	4,580	51.8
Age (Range: 60–106)	69.69	7.29
Marital status		
Married	6,428	72.8
Bereaved, divorced, separated, or never married	2,407	27.2
Education		
Illiterate	2,064	23.4
Primary school	250	2.8
Junior school	3,044	34.5
Senior high school	2,140	24.2
Technical school	918	10.4
College or higher	419	4.7
Ethnicity group		
Han majority	8,193	92.7
Ethnic minority	642	7.3
Religious affiliation		
No affiliation	7,994	90.5
Any affiliation	841	9.5
Living status		
Living alone	1,047	11.9
Living with others	7,788	88.1
Region		
Rural residence	4,569	51.7
Urban residence	4,266	48.3
Personal pension level (Range: 1–5)	3.28	0.99
Number of children (Range: 0–10)	2.55	1.41
ADL (Range: 11–33)	11.57	1.87
IADL (Range: 8–24)	8.87	2.19
Internet use (Range: 0–6)	0.25	0.83
Reading current news	795	9.0
Watching videos	385	4.4
Chatting with others	607	6.9
Shopping	118	1.3
Playing games	243	2.8
Investing in stocks	82	0.9
Social isolation (Range: 6–36)	21.58	5.75
Cognitive function (Range: 0–16)	13.14	3.26
Depressive symptoms (Range: 9–27)	15.43	3.08

TABLE 2 | A hierarchical regression analysis for moderating effects in the relationship between social isolation and cognitive function ($N = 8,835$).

	Model 1 β	Model 2 β	Model 3 β	Model 4 β
Female	−0.05***	−0.05***	−0.05***	−0.05***
Age	−0.16***	−0.16***	−0.15***	−0.15***
Being married	0.04***	0.05***	0.05***	0.05***
Education	0.13***	0.13***	0.12***	0.12***
Han majority	0.04***	0.04***	0.04***	0.04***
Having a religious affiliation	−0.05***	−0.05***	−0.05***	−0.05***
Living alone	0.01	0.02	0.02	0.02
Urban residence	0.13***	0.13***	0.13***	0.13***
Personal pension level	0.06***	0.05***	0.05***	0.05***
Number of children	−0.01	−0.02	−0.01	−0.02
ADL	−0.07***	−0.07***	−0.07***	−0.06***
IADL	−0.12***	−0.11***	−0.11***	−0.11***
Depressive symptoms	−0.11***	−0.11***	−0.10***	−0.10***
Social isolation		−0.06***	−0.06***	−0.06***
Internet use			0.05***	−0.14***
Social isolation × Internet use				0.20***
Adjusted R^2	0.206	0.209	0.211	0.213
ΔR^2		0.003***	0.002***	0.002***

***$p < 0.001$.

2's results demonstrate social isolation was positively related to depression ($\beta = 0.06$, $p < 0.001$), after controlling for the effects of sociodemographic variables and cognitive function. Model 3 included Internet use and reports it was negatively associated with depression ($\beta = -0.11$, $p < 0.001$). Furthermore, Internet use was a more important predictor of depression than social isolation, since the change in R^2 of Step 3 was more substantial than that induced by social isolation in Step 2. Model 4's results indicate the interaction effect of Internet use and social isolation is significantly positive ($\beta = 0.17$, $p < 0.001$). As **Figure 3** shows, the positive relationship between social isolation and depression was weaker for older adults who have a higher level of Internet use.

Gender-Specific Analyses

As shown in **Table 4**, **Figures 4** and **5** same as the results of the total-sample analysis, the moderating effects of Internet use on the association between social isolation and cognitive function/depression were significant in both females and males. Notably, as **Figure 5** indicates, in the Internet-high-use group, the depression levels of the socially isolated male participants were much lower than for female participants.

DISCUSSION

Although the theoretical and practical interest in Internet use among older adults remains high, the evidence testing its impacts on late-in-life health outcomes is limited (1). Some studies even show it has negative effects on the well-being of older adults (12, 47). This study advances the literature by exploring the interplay of social isolation and Internet use on cognitive function and depression/cognitive function among Chinese older adults.

As our study reports, 11.4% of Chinese older adults often used the Internet to engage in at least one activity (e.g., chat with others). First, the prevalence of Internet use was much lower than rates found in previous studies. For example, Yuan (30) reported a 46.48% use rate among elderly Shanghai residents; however, they lived in the commercial and financial center of mainland China with easy access to computers and smartphones. Second, when compared with Internet use in Western studies–53% in

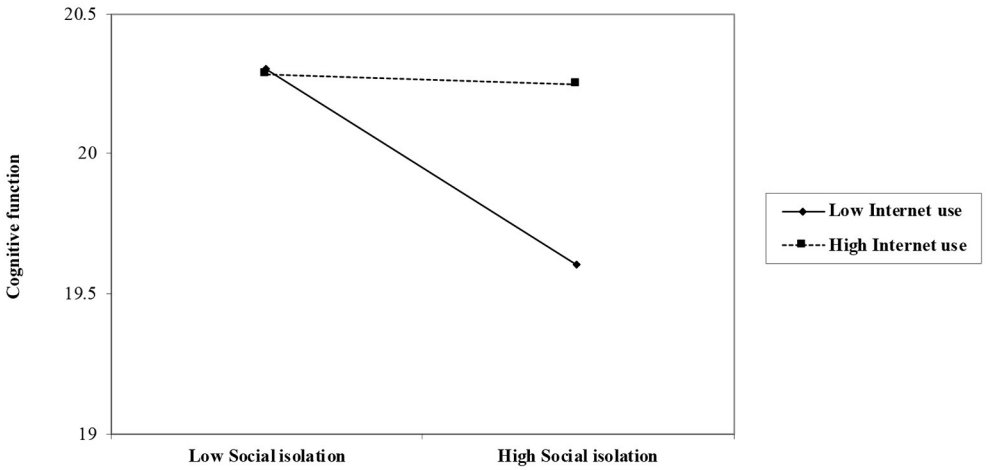

FIGURE 2 | Role of social isolation on cognitive function by levels of internet use among the entire sample ($N = 8,835$).

TABLE 3 | A hierarchical regression analysis for moderating effects in the relationship between social isolation and depressive symptoms ($N = 8,835$).

	Model 1 β	Model 2 β	Model 3 β	Model 4 β
Female	−0.03*	−0.03	−0.02	−0.02
Age	−0.01	−0.01	−0.02	−0.02
Being married	−0.04**	−0.04**	−0.04**	−0.04**
Education	−0.06***	−0.06***	−0.04***	−0.04***
Han majority	0.10***	0.09***	0.09***	0.09***
Having a religious affiliation	0.01	0.01	0.02	0.02
Living alone	0.08***	0.07***	0.07***	0.08***
Urban residence	−0.05***	−0.05***	−0.04*	−0.04*
Personal pension level	−0.05***	−0.05***	−0.04**	−0.04**
Number of children	0.04**	0.05***	0.04**	0.04**
ADL	0.06***	0.06***	0.07***	0.07***
IADL	0.08***	0.07***	0.07***	0.07***
Cognitive function	−0.13***	−0.12***	−0.11***	−0.12***
Social isolation		0.06***	0.06***	0.06***
Internet use			−0.11***	−0.27***
Social isolation × Internet use				0.17***
Adjusted R^2	0.092	0.095	0.105	0.107
ΔR^2		0.003***	0.010***	0.002***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Europe as reported by Kamin and Lang (23) —our research offers novel evidence that Internet use among older adults in China is still less common. But, it is in line with previous studies that suggest that most Chinese older adults lack the digital literacy required to access the Internet, a novelty that appeared when they entered middle or old age (15). Despite many scholars expecting older adults to use the Internet to communicate with others and in turn obtain social support (29), our study identified reading the news as the most common activity for participants (9.0%), rather than chatting with others (6.9%). This echoes Western research showing older adults tend to use the Internet to access information, including news and health-related information (32).

Consistent with the literature (5, 7), our study confirms Chinese older adults who were socially isolated were also vulnerable to higher risks of cognitive impairment and depression. The relationship between social isolation and cognitive function in later life has not been adequately explored, especially in non-Western societies (48). Although quite a few studies conducted in China have identified the negative effects of social isolation on late-in-life depression, most constructed social isolation with a single measure (e.g., marital or cohabiting status) or multiple measures (e.g., family size, living with a spouse, frequency of contact with children, rural residence, participation of social activities) (49). Our findings advanced prior studies by adopting a reliable and valid instrument: the LSNS-6, which has been indicated as a good tool to screen for social isolation among older, community-dwelling Chinese adults (38). Furthermore, the results demonstrate isolation (e.g., infrequent contact with others) in both family and friendship ties was significantly associated with more depressive symptoms as well as cognitive impairment among Chinese older adults.

Our results shed light on the equivocal findings of the extant literature on the effects of Internet use (12, 13). They indicate Internet use was negatively associated with depression while it was positively related to cognitive function. Many scholars tend to explain the negative association between Internet use and depression by theorizing users are seeking emotional support or increased communication (17, 30). Our research demonstrates the Internet's pivotal role for Chinese older adults in providing information-based online activities. That is, among the study participants who reported often using the Internet, 86% did so to find information while 66% sought to chat with others. Thus, it is plausible that because the Internet in contemporary China has been widely used in public service and daily life, the Internet enables older users to access information themselves, which in turn, has positive

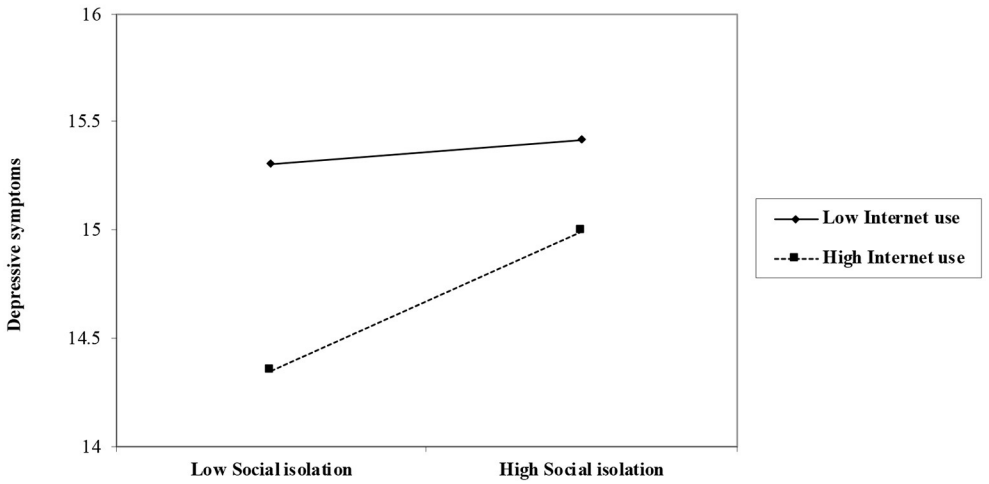

FIGURE 3 | Role of social isolation on depressive symptoms by levels of internet use among the entire sample (N = 8,835).

TABLE 4 | Results of linear regression model for moderating effects in the relationship between social isolation and cognitive function/depression across gender groups (N = 8,835).

	DV: Cognitive function		DV: Depression	
	Female group	Male group	Female group	Male group
	β	β	β	β
Female	/	/	/	/
Age	−0.18***	−0.13***	−0.04*	0.00
Being married	0.04*	0.05**	−0.05**	−0.02
Education	0.15***	0.09***	−0.04	−0.05**
Han majority	0.03	0.06***	0.10***	0.09***
Having a religious affiliation	−0.04**	−0.06***	0.01	0.02
Living alone	0.04*	−0.01	0.09***	0.05**
Urban residence	0.15***	0.10***	−0.03	−0.05*
Personal pension level	0.02	0.08***	−0.04*	−0.03
Number of children	−0.01	−0.02	0.07***	0.01
ADL	−0.07***	−0.05**	0.07***	0.06**
IADL	−0.09***	−0.14***	0.07***	0.06**
Depressive symptoms	−0.10***	−0.11***	/	/
Cognitive function	/	/	−0.11***	−0.13***
Internet use	−0.14*	−0.15*	−0.32***	−0.24***
Social isolation	−0.05***	−0.06***	0.06***	0.06***
Social isolation × Internet use	0.20***	0.20***	0.23***	0.13*
Adjusted R^2	0.223	0.195	0.113	0.101

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

effects on their psychological well-being. Connecting this result to the stress-coping framework, our findings underscore the significance of access to information as coping resources in relation to lowering depression levels among Chinese older adults. Western research has also confirmed informational support could allow older adults to accumulate the resources necessary to cope with common daily stressors and mitigate depressive symptoms (50).

Also in line with previous Western studies (22, 23), older adults in our sample who often used the Internet had a better cognitive performance. One possible explanation may be that as Kamin and Lang (23) suggested, older adults might obtain the cognitive benefits of online activities through handling technological tasks and challenges. Moreover, when using the Internet contributes to more cognitively stimulating environments, it can be a source of cognitive plasticity for older

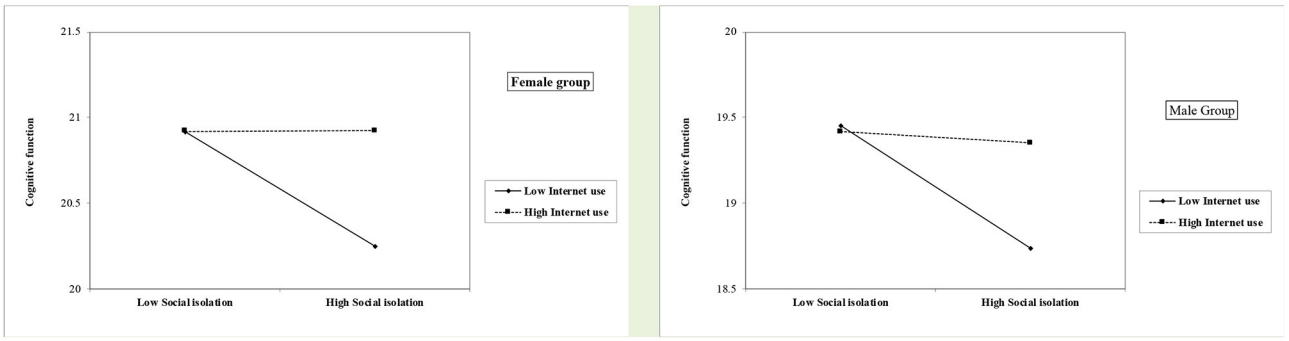

FIGURE 4 | Role of social isolation on cognitive function by levels of internet use among the female and male group.

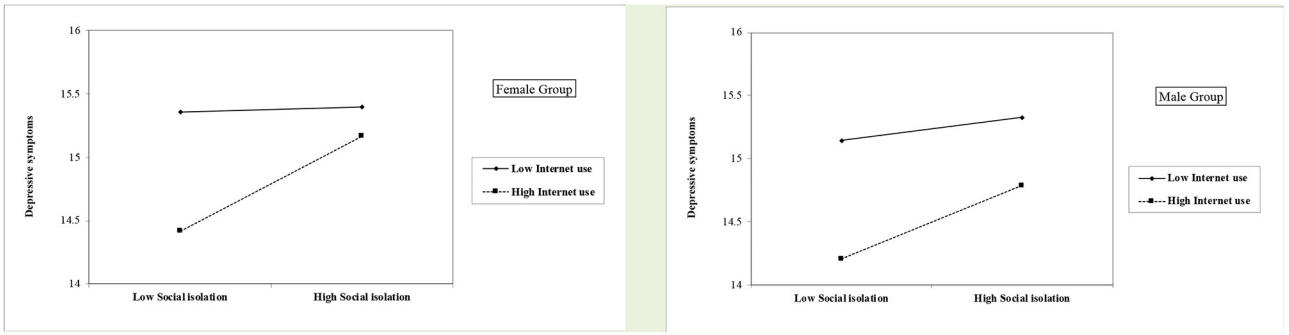

FIGURE 5 | Role of social isolation on depressive symptoms by levels of internet use among the female and male group.

people (51). However, given the cross-sectional nature of our investigation, another possible explanation was suggested by Czaja et al. (52); they found cognition function would influence the use and adoption of digital technology in late life. In another word, keeping up with Internet developments and learning to use a new device were easier for older adults who were less cognitively impaired; thus, they are more likely to engage in more online activities.

Furthermore, our study went beyond existing knowledge and further indicates the path between social isolation and depression/cognitive function was moderated by older adults' Internet use. Those with lower Internet use exhibited a greater association between social isolation and worse cognitive function, compared to those using the Internet more. Similarly, older adults with lower Internet use reported a stronger association between social isolation and depression. One speculation is that as Elliot et al. (14) pointed out, the Internet use may have a moderating effect because it acts as a coping mechanism in response to late-life health challenges. Thus, Internet use may provide socially isolated older adults with greater opportunities for social support. Such a moderating effect of Internet use in gerontology has been examined by limited studies. Thus, our study advanced the gerontology literature and provided supporting evidence for the protective effects of Internet use among Chinese older adults against a specific stressor of being socially isolated. The current study further conducted the gender-specific analyses to examine whether the moderating effects of Internet use differ among females and males. The results show the moderating effect of Internet use was significant for both males and females. Additionally, among those who use the Internet more, the depression level of socially isolated male participants was much lower than for females. One possible explanation may be Internet use might buffer the effects of social isolation on late-in-life depression for males, compared with females. However, this finding echoes the suggestion of Hunsaker and Hargittai (20). Future research on a more nuanced look at the relationship between gender and Internet use among older adults is needed.

Certain limitations should be considered when interpreting our findings. First, the cross-sectional nature of the data could preclude unequivocal conclusions regarding the causal relationships between various variables (e.g., social isolation, Internet use) and late-in-life depression/cognitive function. Future studies should employ a longitudinal design to further establish the validity of temporal relationships and rule out potential bias. Second, the limitation of secondary data prohibited us from including more online activities (e.g., searching for health-related information, online dating), which have been explored in Western studies. Further investigation with more items to fully capture the diversity of Internet use by older adults is needed to replicate our results and to explain the moderating

role of Internet use. Third, as described previously, our study conducted gender-specific analyses and found the moderating effect of Internet use might be more protective for males, but the gender differences in this topic are still not fully explained. Hence, further attention is warranted on aging populations' heterogeneity in Internet use, especially gender differences.

Despite these limitations, our study offers significant, practical implications. Overall, our findings suggest that Internet use could buffer the negative effects of social isolation on increasing depression and cognitive impairment among older adults. It highlights the importance of improving Internet accessibility, digital literacy, and positive attitudes of Chinese older adults, especially those who are socially isolated. First, due to the late popularization of the Internet, a digital divide exists among Chinese older adults whereby older adults with higher socioeconomic status, including higher level of education or income, or an urban residence (53) are more likely to access the Internet. Given the protective role of Internet use seen in our findings, it is urgent to remove barriers at the macro level through increasing the coverage of infrastructure in rural areas and providing free Internet for older adults. Also, the design of computers, the Internet, and mobile communication devices should consider older adults' characteristics, including cognitive abilities, declining visual and auditory abilities, and use habits, to design more age-friendly products. Second, because face-to-face social support services (peer support groups) might be less applicable during the COVID-19 pandemic, the Internet and social media apps could serve as an alternative for coping with social isolation or loneliness. Hence, to prevent negative experiences due to technical difficulties, frontline practitioners should engage older adults in technical training programs to help them improve their digital literacy and build their capacity to use the Internet. Finally, our study implies that older adults who are more socially isolated might benefit more from using the Internet. Considering the high proportion of empty nests among Chinese older adults, a targeted technical training service on a nationwide scale for older adults (particularly those with narrow social networks and "empty-nest elders") may be a necessary step to prevent or reduce the adverse impacts of social isolation.

CONCLUSION

In conclusion, the current study identified that Internet use among older adults in China is still less common, with 11.4% often using the Internet to engage in at least one activity. And reading the news was the top usage for Chinese older adults, instead of chatting with others. Our results shed light on the equivocal findings of the effects of Internet use and indicated Internet use was negatively associated with depression while it was positively related to cognitive function. We further expanded our understanding and indicated that Internet use might buffer the negative effects of social isolation on increasing depression/cognitive impairment among older adults. Recommendations for service practice and future research are discussed.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: We need to seek consent of the CLASS research team to disclose the data to the journal if our paper is accepted. Requests to access these datasets should be directed to prof. Zhai Zhenwu, zhaizw@ruc.edu.cn.

AUTHOR CONTRIBUTIONS

YL conducted the first statistical analysis. All authors discussed paper structure and contributed to different part of the literature and composed the first draft together.

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Technological Applications Contributing to Relieve Care Burden or to Sleep of Caregivers and People With Dementia: A Scoping Review From the Perspective of Social Isolation

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The need for care will increase in the coming years. Most people with a disability or old age receive support from an informal caregiver. Caring for a person with dementia can be difficult because of the BPSD (Behavioral and Psychological Symptoms of Dementia). BPSD, including sleep disturbance, is an important factor for a higher care load. In this scoping review, we aim to investigate whether technology is available to support the informal caregiver, to lower the care burden, improve sleep quality, and therefore influence the reduction of social isolation of informal caregivers of people with dementia. A scoping review is performed following the methodological framework by Arksey and O'Mally and Rumrill et al., the scoping review includes scientific and other sources (unpublished literature, websites, reports, etc.). The findings of the scoping review shows that there are technology applications available to support the informal caregiver of a person with dementia. The technology applications mostly contribute to lower the care burden and/or improve sleep quality and therefore may contribute to reduce social isolation. The technology applications found target either the person with dementia, the informal caregiver, or both.

Keywords: informal caregiver, dementia, technology, loneliness, sleep, social isolation

INTRODUCTION

In 2019 there were 703 million older persons aged 65 or over and in the coming decades, this number will double to more than 1.5 billion persons in 2050 (1) that, according to Alzheimer's Europe (2019), there are almost 9.8 million people with dementia in Europe (2). This number will almost double to 18.8 million people in 2050. With these numbers of older people (with dementia) the need for care will also increase. Most people with a disability or older age-dependent on support from an informal caregiver (a relative or friend) (3). In Europe, estimates suggest that approximately 80% of all long-term care is provided by informal caregivers (4). This also applies in the Netherlands (5).

Informal caregivers can experience a higher level of stress and depression. They experience a lower level of subjective wellbeing compared to non-caregivers and they encounter a greater risk of developing physical health problems. Also, they may experience a lack of social activities (6). Depending on the quality and duration of the relationship between the caregiver and the person with dementia, the experience of adverse physical and psychological health consequences may vary. With increasing numbers of years of care, the risk of physical and psychological health threats increases (7). Caring for a person with dementia can be difficult because of the behavioral and psychological symptoms of dementia (BPSD). BPSD is an important factor for a high care load of informal caregivers (8). BPSD affects about 90% of people with dementia at any given moment (9). BPSD comprises sleep disturbances, aggression, anxiety, and wandering (9). A review of Cross et al. (7) shows that informal caregivers perceive their situation as permanence and they experience a sense of being tied-in, being always alert, unappreciated, feeling trapped, like a prison, pulled in all directions, and at times, being in an unreal situation. These feelings with emotions of distress, hopelessness, depression, tiredness, exhaustion, frustration, guilt, negative thoughts, loss of patience, and isolation. The feeling of care burden may result in a decrease in the own quality of life of the informal caregiver but may also harm the person with dementia. The care burden and the possible decrease of quality of life make social and professional support essential (10). In the Netherlands, 15% of the informal caregivers experience loneliness when they live with a person with dementia (11).

This scoping review will focus on the sleep of informal caregivers of people with dementia, as a study indicates that they had poorer perceived sleep quality and shorter sleep duration than age-matched non-caregivers and population-based estimates (12). 50–70% of the informal caregivers of a person with dementia have sleep complaints (13). Several factors may disturb sleep, including environmental factors, physical and mental disorders (14). Sleep disturbance can worsen mental, physical, and cognitive health (12). In dementia the caregiver's sleep can be disturbed because of the stress and the increased cognitive burden, having to think and remember for two. Because of BPSD, people with dementia exhibit sleep disturbance and unhealthy sleep patterns, including short sleep duration, fragmented sleep, altered circadian rest/activity patterns, and an increase of sleep-disordered breathing (15). Research by Bubu et al. (15) shows that about 45% of persons with dementia have sleep disturbance. This can disturb the sleep of informal caregivers directly, and subsequently can worsen the ability to provide care effectively. In addition, decreased sleep quality has been associated with negative mindsets, depression, and anxiety which–in turn–can negatively affect the manner of care for the person with dementia (12).

The scoping review is based on the hypothesis that an informal caregiver is an important person in the life of a person with dementia. The care for a person with dementia who is still living at home can be tough, and even tougher when BPSD is involved; the latter being common. Being an informal caregiver often means experiencing a care burden, that can cause poorer sleep quality. In addition, the responsibility for taking care of a person with dementia in combination with poor sleep quality influences the social participation of the informal caregiver (**Figure 1**). The hypothesis is that (e)assistive technology should contribute to (a) lower the care burden, (b) improve sleep quality, and therefore (c) may positively influence the reduction of social isolation of informal caregivers of people with dementia.

The research question used for the scoping review is "Which technology is available to caregivers to reduce the negative effects of nightly activities from the person with dementia in the home setting?."

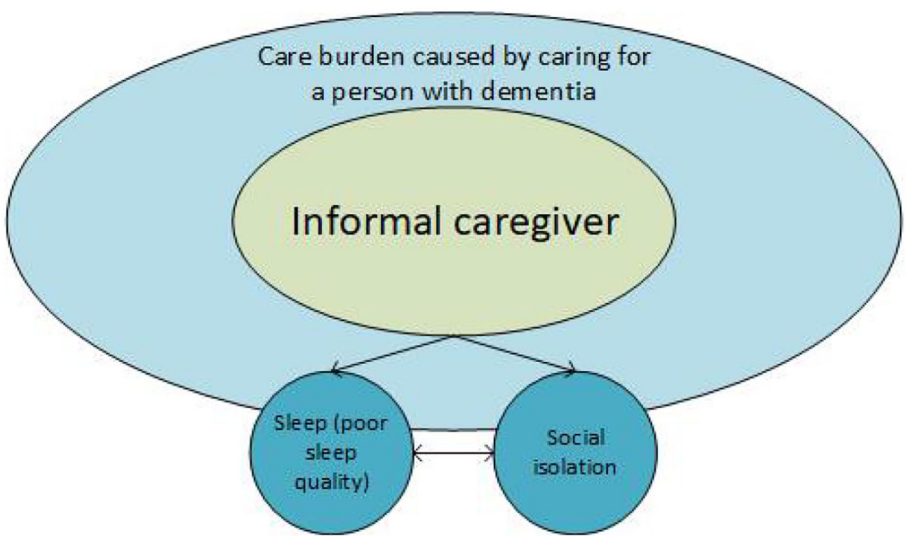

FIGURE 1 | Simple illustration of factors; sleep quality; care burden and social isolation affecting informal caregivers of person with dementia.

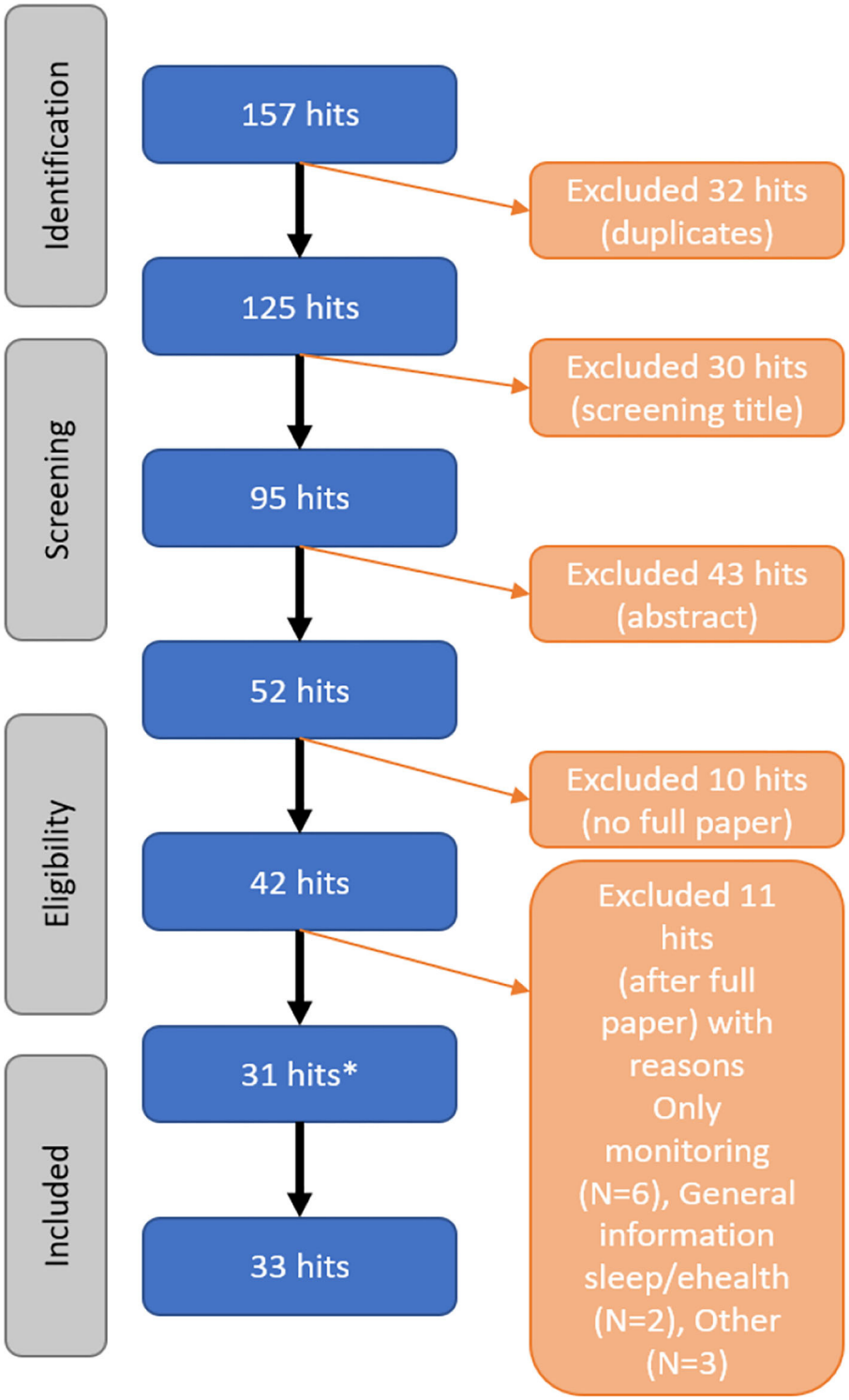

FIGURE 2 | Flowchart of the screening process of the literature (*, added via Snowball-method).

TABLE 1 | Overview of the technological applications contributing to lower the care burden, improve sleep, and/or reducing social isolation.

Contribute to	Scientific *N*=	Other *N*=
Lower care burden	13 (21, 23, 24, 34–43)	19 (28–31, 33, 44–57)
Improve sleep	5 (13, 43, 58–60)	6 (61–66)
Social isolation	0	4 (67–70)
Social isolation/Improve sleep	1 (71)	0
Lower care burden/Improve Sleep	14 (22, 25–27, 72–81)	2 (32, 82)
Lower care burden and social isolation	0	1 (83)

METHODS

Following the methodological framework by Arksey and O'Mally (16) and Rumrill et al. (17), the scoping review includes scientific and other sources (unpublished literature, websites, reports, etc.). In short, the following steps need to be taken: (1) identify the initial research question(s), (2) identify the relevant studies, (3) study selection, (4) charting, and (5) collating, summarizing, and report the results and optional (6) consultation stage). In this first exploration, step 6 is not performed, because with this review an insight is gained about which technological innovations are studied and or on the market supporting the hypothesis.

Identify and Selection

Search

A literature search (between January 2021 and May 2021) was conducted in Web of Science, the Association for Computing Machinery, the Institute of Electrical and Electronics Engineers (IEEE) Xplore Digital Library, ScienceDirect, and Cinahl. All libraries were searched for articles about dementia, technology, and sleep.

Depending on the database a search strategy was performed on abstract, title, and/or keywords. The following keywords were used: Dementia OR "Alzheimer's disease" AND Technology OR "internet-based intervention" OR innovation OR ICT OR robot AND Sleep OR "Sleep Initiation and Maintenance Disorders" OR "disorders of initiating and maintaining sleep" OR "Sleep disorder" OR "sleep disorders" OR Night OR "bedtime." To adjust the search to the nature of the different databases, one change was necessary. In Science Direct the following keywords are used: Dementia OR "Alzheimer's Disease" AND Technology OR "internet-based intervention" OR innovation AND Sleep OR "Sleep disorder" OR Night, because of the restriction on Boolean operators. In addition to the database search, reference lists were reviewed to identify additional studies. Furthermore, reference lists of the relevant articles, social media, and other sources (e.g., reports from knowledge institutions and governments, overview pages) were searched for relevant publications and information utilizing. Google, Google Scholar, websites of knowledge institutions, YouTube, and Twitter are searched with terms like "technology," "dementia," "sleep."

Selection

A first selection of the literature is made by reviewing only titles and abstracts. Including criteria are:

- Focus on dementia care.
- Focus on technology that can support the informal caregiver and/or the person with dementia before/during the night.
- Published in the English language.

The selection of studies was divided into two phases. In phase one, the first author (CH) preselected relevant studies based on title, abstract, and keyword; and in phase two, the co-authors (EH & HK) selected (the preselected) relevant articles based on abstract only.

Also, other sources were selected. Including criteria are based on language (English or Dutch), and relevance for the aim of this review. From these other sources, full-text versions were obtained and read in their entirety.

Charting and Collecting

The literature studies and other sources included in this review are analyzed alongside the hypothesis that care for a person with dementia by informal caregivers is influenced by care burden, sleep quality, and therefore may cause social isolation. Besides that, the technology mentioned in the articles and other sources was categorized based on the so-called Pyramid of Technology, to indicate the level of the technology used (18). This view on technology describes the various levels at which technology may function in life in analogy with Maslow's Hierarchy of Needs, which describes human requirements (19). Similar to Maslow's model, technologies can move up and down. A lower stage needs to be fulfilled before a technology application can go to the next stage. New technologies are often seen as artificial but over time become accepted, familiar, and eventually even established. The different levels according to van Mensvoort are (1) envisioned (idea), (2) operational (tested small scale), (3) applied (available in practice), (4) accepted (daily life), (5) vital (second nature), (6) invisible (not even seen as technology), and (7) naturalized (human nature). The naturalized phase is rarely attained, most technology climb no higher than halfway up. When technology reaches this stage it either stabilizes or returns to lower levels because of new emerging technologies (18).

The first author analyzed and categorized the included studies based on the full papers. Articles were categorized by the authors, based on context or available outcomes on contributing to (a) lower the care burden, (b) improve sleep quality, and (c) may positively influence the reduction of social isolation of informal caregivers of people with dementia, using the four-eyes principle (20). In addition, the level of the technology or technologies mentioned was categorized as well based on the Pyramid of Technology. Furthermore, the type of study, number of participants, and duration of the study were noted. Both the second and third authors categorized the articles based on the title and

TABLE 2 | Technology applied in literature studies.

References	Pyramid of technology level	Technology	Context	Study	Duration	Number of participants
Tsolaki et al. (34)	1	Not-intrusive sensors, ambient depth camera, tags, wristwatch, and voice records. Monitoring with technology is only beneficial when there follows an action when necessary.	PwD living alone	O	N/A	N/A
Cahill et al. (35)	2	Automatic Night and Day calendar, lost item locator, automatic night lamp, gas cooker device, and picture button telephone	PwD alone or together	C	N/A	20
Kang et al. (36)	2	Wearable and environmental technology for monitoring and alerting. Also an electronic pillbox and sensors and monitors.	N/A	R	N/A	N/A
McKenzie et al. (37)	2	Safe Home Program, for ongoing surveillance, provision of care, prevention of injuries, and improving home safety. Using motion sensors, camera, proximity range alarm, medication alarm, locating technology, multiple sensors for safety, and detectors (e.g., smoke and water).	PwD alone or together	R/D	3 m	60
Meiland et al. (38)	2	Rosetta system, a mobile device, sensors, automatic detection of emergencies. System offers reminders for activities, a picture dialing system, radio and music button, activity support [e.g., making coffee and safety warning (e.g., an open window), monitoring, prevention and emergency response, fully automatic detection of emergencies].	PwD alone or together	P	N/A	50
Gitlin et al. (39)	2	WeCareAdvisor, a web-based platform that provides information about dementia, tips and an approach to create treatment plans (based on behaviors) with tips and evaluation. The system is installed on an iPad.	PwD alone or together	RCT	1 m	57
Lazarou et al. (40)	3	Wearable sensors to detect sleep patterns, physical activity, and activities of daily living	PwD alone	C	3/4 m	4
Husebo et al. (42)	3	Seven studies used wearable technologies (multiple sensor systems, ankle or wristband, or a combination of both). They identified 12 studies that used sensor-based motion detection (non-wearable). Twelve studies were found that utilized sensors rays placed in the living environment. Three additional studies were added with a unique technological approach, a robot, a tablet tool for text analysis.	N/A	SR	N/A	N/A
Rawtaer et al. (41)	3	System to detect changes in behaviors with passive infrared motion sensors, beacon tags, medication box with sensor, bed sensor, and a wearable.	PwD alone	CS	2 m	49
Leyhe et al. (84)	3	Sensor system to support age in place, with wearable sensors, ambient sensors, or a combination of these. Sensors which can monitor and share activities.	N/A	O	N/A	N/A
Topo et al. (21)	4	Automatic Night and Day calendar	PwD alone or together	A	3 m	50
Abraha et al. (23)	N/A	Sensory stimulation interventions, cognitive/emotion-oriented interventions, behavior management, and other therapies (e.g., exercise therapy, animal-assisted therapy). Music therapy and behavioral management therapies were effective for reducing BPSD.	N/A	SR	N/A	N/A
Anderson et al. (24)	N/A	Several interventions are discussed. Behavioral interventions with the COACH system. A cognitive assistive technology that provides task guidance (e.g., hand washing). BESI is a system of body-worn and in-home sensors to detect agitation and its environmental triggers.	Home and nursing home	R	N/A	N/A

1, envisioned; 2, operational; 3, applied; 4, accepted; C, Case study; A, Assessment study; R, Review; P, Participatory design study; D, Demonstration project; O, Opinion; SR, Systematic Review; CS, Cross-sectional study; m, months; N/A, not applicable.

TABLE 3 | Technology applied in studies found from other sources.

Name	Pyramid of technology	Technology
SEM (Watchsem)	1	SEM (Sleep, Eat, Move) is a watch application to support people with early-onset dementia. The application can support daily rhythm based on sleeping, eating, and moving. With reminders, by using recognizable pictures and voice the app supports to keep daily rhythm (44).
Empathic Dwelling	2	The Empathic Dwelling is a research program that focuses on three main building elements in a building, floor, walls, and roof. The dwelling thinks along with the person with dementia, by using smart sensors for example. COOK3R is a smart and interactive cooktop that thinks along with a person with dementia during cooking. The COOK3R gives spoken instructions, light and sound signals, and automatically stops the heating when the food is ready. Interactive Living is using projection, light and sound signals to support people with dementia with their daily activities. For example, getting up on time, eating and drinking, and going to bed on time (45).
HAGU (Jingcailiu)	2	Hagu is a vest that tightly enfolds its owner giving the sensation of being hugged, this can be supportive in making life more comfortable (46).
Ritme	2	Ritme can support the daily structure of someone. The app generates a signal at a certain time, and this only stops when someone has scanned the correct QR code (for example, in the kitchen) (47).
AAL eWare	2	AAL project "Early Warning Accompanies Robotics Excellence" is focused on improving the lifestyle of people with dementia and their caregiver (s). In the project, lifestyle monitoring is integrated with social robotics (48).
AAL ReMIND	2	ReMIND is an AAL project in which a nursing robot (James) is combined with a tablet. It should be an interactive agenda, library of music, pictures, and exercises that guarantee the desired stimulation of patient and caregiver (49).
AAL CARE smart sensor	2	The AAL Care project wants to realize an intelligent monitoring and alarming system. (50)
AAL MedGUIDE	2	AAL project MedGUIDE developed a digital platform that brings together informal caregivers, care professionals, pharmacists, and people with dementia themselves. The system collects subjective (self-report) and objective data (sensors), to provide an up-to-date view on the state of needs of people with dementia. MedGUIDE uses big data analysis to detect changes in patients' routines, to minimize the side effects of medication. The system supports medication adherence by direct reminders (51).
AAL MEMENTO	2	AAL MEMENTO is a tool to create memories in everyday life. It is a sort of picture, voice, and video diary for people with dementia (52).
TimeSteps	2	TimeSteps is an application to support people with dementia with awareness of time and remind them of appointments (53).
HUME (Mentech Innovation)	3	HUME is based on sensors, behavioral models, and machine learning and can recognize emotions (54).
Tessa (Tinybots)	3	Tessa looks like a plan pot and is capable of speaking and can provide alerts, reminders, verbal guidance, and encouragement to patients (55).
Felix (Happybots)	3	Felix is a social robot that can help people express feelings (56).
OER	3	OER is an easy-to-use music player. The music player can be used by people with dementia because of the ease of use (57).
DayClocks	4	DayClocks have different functions, it is a clock (analog, digital, day and part of the day), but family and informal caregivers are also able to send messages, appointments, and pictures to the DayClock of a person (28).
Don't forget it	4	Don't forget it is an application which helps people to remember appointments. The solution is a display with appointments and other important information (29).
Bbrain Family D2 Dementieklok	4	BBrain enables older adults to continue functioning independently longer, even with dementia. A BBrain tablet supports structure, creates tranquility and engagement. It is also possible to communicate via BBrain with messages, pictures, and video calls with other people (30).
Domotica	4	Automatic control of electronic devices in the home. The devices are connected to the internet, so you can control them remotely (33).
JustoCat	4	An interactive robotic cat, as alternative of a real pet (31).

1, envisioned; 2, operational; 3, applied; 4, accepted.

abstract. No conflicts occurred between the scoring between the first and second author and between the first and third author.

Other sources are analyzed and categorized in the same way by the first author only.

RESULTS

A total of 157 articles are found, 32 of the articles were duplicates. Thirty articles are excluded based on title and 43 articles are excluded after reading the abstract. From 10 of the articles, no

TABLE 4 | Technology applied in literature studies.

References	Pyramid of technology level	Technology	Context	Study	Duration	Number of participants
Rose et al. (43)	1	Body sensors.	Home	C	5/7 w	50
Wang et al. (58)	2	Monitoring and support system, using sensors.	PwD alone	C	3 m	2
Aarts et al. (59)	2	Dynamic lighting.	Nursing home	C	N/A	6
Jones and Moyle (60)	2	Customized, removable, washable, quilted cover placed over a pillow. With music and Intrasound TechnologyTM.	Care facility	F	4 w	4
Pu et al. (13)	3	Paro robot seal.	Nursing home	RCT	6 w	41

1, envisioned; 2, operational; 3, applied; F, Feasibility study; C, Case study; RCT, Randomized Controlled Trial; m, months; w, weeks; N/A, not applicable.

TABLE 5 | Technology applied in studies found from other sources.

Name	Pyramid of technology	Technology
Muziek in de nacht/Music at night	2	"Muziek in de nacht" is an application for people with sleep issues. The app responds to voice sounds, to then calm the client with quiet music or a familiar voice, which is played automatically (61).
Sparckel	2	Sparckel is a biodynamic lighting armature. In this lighting the illuminance level and the color temperature are combined in the right proportion and varied throughout the day, resembling a daylight curve (62).
Brise AI Guardian Angel	2	BRISE AI Guardian Angel senses and analyses your home environment, it diagnoses and recommends action to protect you and intelligently improves your home or work ecosystem to help prevent, ease, solve asthma and allergic symptoms for a healthy deep breath (63). An uncomfortable environment, can trigger BPSD.
Somnox	3	Somnox is a robot-like cushion that helps people fall asleep, by calming the mind and body (64).
Lyla Sleep Coach	3	Lyla Sleep Coach is based on cognitive behavioral therapy. Users of the application learn to get rid of their incorrect sleep behavior and adopt the correct behavior 6 weeks (65).
Qwiek.snooze	3	Qwiek.snooze is a smart music pillow designed for people with dementia to have a better sleep. The pillow helps to relax and to fall asleep with music (66).

2, operational; 3, applied.

TABLE 6 | Technology applied in studies found from other sources.

Name	Pyramid of technology	Technology
Toolooba	1	Tolooba develops software that retrieves 'hidden' memories of people with dementia. With the software, memories activate by using images selected by an algorithm, in this way the software can help to reconnect, improve happiness, wellbeing, and interaction between a person with dementia and carer(s) (67).
AAL Sense-Garden	2	The Sense-Garden is a room in which people with dementia accompanied by a caregiver or family member walk into his/her history and memories (68).
AAL MI-Tale	2	An interactive game to recall memories of people with dementia. Using historical pictures and videos, also from the user (69).
123 Familie	3	123 Familie is a video call application for people with dementia. The application has an intuitive interface and is easy to use. It is also possible to use an automatic pick-up function when necessary (70).

1, envisioned; 2, operational; 3, applied.

full paper was available. And after reading the full paper 11 articles are excluded. Via the snowball method, two additional articles are included. In total, 33 articles (scientific) are included in this scoping review, using the literature search described above (**Figure 2**).

Furthermore, and as described above, other sources were used to include available technology not yet described in the scientific literature resulting in the evaluation of 32 additional technology applications.

TABLE 7 | Technology applied in literature studies.

References	Pyramid of technology level	Technology	Context	Study	Duration	Number of participants
Tanaka et al. (71)	2	Human-type communication robot.	PwD alone	RCT	8 w	34

2, operational; RCT, Randomized Controlled Trial; w, weeks; N/A, not applicable.

Overall Results

Using the Pyramid of Technology, most ($N = 26$ out of 33) of the included studies described technology in the envisioned (1), operational (2), and/or the applied (3) phase. Only in two studies (21, 22), the described technology was in the acceptance (4) phase. Three (23–25) studies do not describe a specific technology application. In two (26, 27) studies the exact level of the applied technology could not be assigned to one level only.

Looking at technologies applied as described in other sources, most ($N = 26$ out of 32) were in the envisioned (1), operational (2), and/or the applied (3) phase. Six technologies were (almost) in the acceptance phase. These technologies contribute to keeping a daily rhythm (28–30) or contribute to calming down a person with dementia (31) or contribute to physical activity (32) or safety/comfort (33).

The described technology applications (literature studies and other sources) mainly focused on lowering the care burden ($N = 32$). In some ($N = 18$) cases, the described technologies may contribute to for example lower the care burden and improve sleep. In **Table 1** the results are shown, the technology applications may contribute to e.g., improve sleep, but this is not necessarily scientifically proven in the included studies.

In **Tables 2**–**10**, the technology applications both found in the literature studies and other sources are ordered according to the level of the Pyramid of Technology. The literature studies are ordered on publication year as well and we add the kind of study. We take into account the Pyramid of Evidence when it comes to the level of evidence, in which Systematic Reviews of RCT are the highest level and Opinions the lowest (85).

Lower Care Burden

As mentioned (**Table 1**), 13 studies describe technology applications that contribute to lower the care burden of an informal caregiver. Besides that, 19 technology applications are identified from other sources.

Most ($N = 32$) of the technology applications contribute to lower the care burden of the informal caregiver of a person with dementia. There are different types of technology applications found and also the phases according to the Pyramid of Technology differ. The Automatic Day and Night calendar were described twice in literature (21, 35), and the same sort of technology (28, 29, 53) was found in other sources. This sort of technology works with reminders to support daily rhythm. Concerning the use of in-home sensors, nine studies (24, 34, 36–38, 40–42, 84) described the use of in-home sensors, and four applications (33, 48, 50, 51) from other sources utilize them as well. Wearable devices are mentioned six times (24, 36, 40–42, 84) in the included studies and six times (31, 44, 46, 47, 53, 54) in other sources. In the scientific papers, no robot-based technology application was found, four applications (31, 48, 55, 56) from other sources make use of robotics.

Improve Sleep

Five studies indicated a technology application that contributes to improved sleep and six applications were added from other sources.

To improve sleep, 11 technology applications were detected. None of these applications were yet in the accepted phase according to the Pyramid of Technology. Regarding scientific evidence, one study (58) was published in 2010, the others ($N = 4$) 2015 or later. Furthermore, three were case studies (58, 59, 86), one a feasibility study (60), and one RCT (13). Looking at the applications, two (59, 62) technology applications were based on lighting, and three were a sort of pillow people can use. Music was used in four technology applications (60, 61, 64, 66) and sensor technology was used in two applications (58, 63).

Social Isolation

Four technology applications targeting the reduction of social isolation were only found in other sources, none in scientific literature.

Three (out of 4) technology applications (67–69) focused on memories of people with dementia to support the conversation. One technology application (70) was used for video calls.

Social Isolation and Improve Sleep

In this review, one technology application was found which targets the reduction of social isolation and improving sleep.

The technology application was described in a scientific paper presenting the results of an RCT using a human-type communication robot (71).

Lower Care Burden and Improve Sleep

This paragraph describes the technology applications aiming at lowering the care burden and improving sleep. A total of 16 technology applications are given in **Tables 8**, **9** below.

The technology applications intending to lower care burden and improve sleep were located relatively low in the Pyramid of Technology, only two (32, 87) were in the accepted phases. The others ($N = 13$) were in the operational and/or applied phase, from one application this information was missing24 (25). One technology application was described twice in literature (74, 75). Also, Paro, the robot seal is mentioned twice (27, 81) in literature. Six technology applications were a combination of sensors and another technology (72–75, 78, 79).

TABLE 8 | Technology applied in literature studies.

References	Pyramid of technology	Technology	Context	Study	Duration	Number of participants
Rowe et al. (72)	2	CareWare gives alerts when a person leaves their bed and tracks them as he/she moves about the house.	PwD alone or together	RP	12 m	53
Rowe et al. (73)	2	Monitoring system which gives alerts when a person leaves their bed.	PwD alone or together	CT	1 y	49
Martin et al. (74)	2	NOCTURAL, see Agusto et al. (75).	Home	P	3 m	8
Augusto et al. (75)	2	NOCTURAL, the system contains audio activity (music and spoken word), visual activity (images displayed on a device), combination (audio and visual), sequenced lighting guidance.	PwD alone or together	UCD	N/A	9
Radziszewski et al. (76)	2	Night Assistance System (NAS) with a monitoring and assistance phase. Collects environmental data with sensors and physiological data from worn sensors. Effectors are e.g., a table lamp, LED bulbs, light reminders and paths, and a media center.	PwD alone or together	E	3 m	4
Williams et al. (77)	2	FamTechCare intervention provides dementia strategies based on video recordings that are assessed by experts.	PwD together	RCT	3 m	42
Ault et al. (78)	2	NWDD (Night-time Wandering Detection and Diversion system), an assembly of components from Samsung Smart Things, SONOS, Ideal Security, and Ecolink sensors. There is a motion sensor, a multipurpose sensor, a door and window sensor, and a pressure mat (in bed). The system reacts when the person with dementia leaves the bed.	PwD alone or together	PL	12 w	5
Obayashi et al. (79)	2	Combination of technology, a sheet-shaped body vibrometer with a communication robot.	Nursing home	PC	4 w	15
Lussier et al. (80)	2	AAL-system with passive infrared sensors, magnetic contact sensors, and smart electric switches. The system can identify trends in sleep, outing, cooking, mobility and hygiene activities.	PwD alone	C	490 d	1
Gong et al. (26)	2 (drybuddy) 3 (TEMPO) 4 (microphone)	A system, with a sensing layer with mainly three types of sensors for detecting wetness, nighttime agitation, and speech outbursts. In the system, the DryBuddy device, microphone, and TEMPO sensors are used.	PwD alone or together	C	5/7 d	12
Saragih et al. (27)	2 (Kabochan) 2 (Bomy) 3 (NAO) 3 (Paro)	In 12 of the studies Paro is used (one combined with NAO robot), in 2 studies social robot Kabochan is used and in one study, robot Bomy is used.	Nursing home and home	SR	N/A	N/A
Moyle et al. (81)	3	PARO-robot seal, a therapeutic pet-type robotic. It is used as a promising alternative to animal-assisted therapies for residents with dementia. Paro can move his fins and make sounds.	Nursing home	CRCT	10 w	28
Jones et al. (22)	4	Personal music on a MP3-player.	N/A	SR	N/A	N/A
Van Hoof et al. (25)	N/A	Light can improve cognition, mood, and behavior, sleep, and vision when properly installed in the dwelling of a person with dementia	PwD alone or together	O	N/A	N/A

2, operational; 3, applied; 4, accepted-E, Evaluation; PC, Proof-of-concept; CRTC, Clustered Randomized Controlled Trial; UCD, User Centered Design; P, Participatory design study; RP, Randomized Pilot; CT, Controlled Trial; PL, Pilot; O, Opinion; SR, Systematic Review; C, Case study; d, days; w, weeks; m, months; y, year; N/A, not applicable.

TABLE 9 | Technology applied in studies found from other sources.

Name	Pyramid of technology	Technology
VitaPillow	2	Vita is an interactive cushion for people with dementia. The cushion can play music or personal audio files by touching one of the six textile touchpads (82).
Silverfit Alois	4	SilverFit contains activities to stimulate people to move, make contact, do a cognitive game, or relax. Silverfit is a system with a display and a 3D motion-sensing camera to detect the player(s) (32).

2, operational; 4, accepted.

TABLE 10 | Technology applied in studies found from other sources.

Name	Pyramid of technology	Technology
CareRiing	3	CareRiing can be seen as a smart answering machine, this is filled with phrases and words by family. A person with dementia can call the Care-Riing number at any time of the day and with speech recognition and AI the correct phrases will be played (83).

3, applied.

Lower Care Burden and Social Isolation

One technology application from other sources, the CareRiing innovation, targeted to lower care burden and reduce social isolation.

DISCUSSION

The hypothesis was that technology applications contribute to (a) lower the care burden, (b) improve sleep, and therefore (c) may contribute to reducing social isolation of the informal caregivers of people with dementia. Therefore, the research question for this exploration was "Which technology is available to caregivers to reduce the negative effects of nightly activities from the person with dementia in the home setting?."

Social isolation of informal caregivers of people with dementia can have different causes such as stress, shrunken personal space, and diminished social interaction caused by the care role, feelings of powerlessness, and helplessness (88). As dementia progresses, the caregiver has to give up their job and/or has no time for any social activities or gatherings. Their lives only revolve around the care of the person with dementia. Informal caregivers may be feeling ignored, abandoned and isolated (89). According to Pearlin et al. (90) stress of an informal caregiver is caused by several contextual factors: the primary stressors of the illness (such as BPSD), secondary role strains, and intrapsychic strain such as personality, competence, and role captivity of the informal caregiver. Caregiver burden has been defined as a negative reaction to the impact of providing care on the informal caregiver's social, occupational, and personal roles by Sherwood et al. (91). Caregiver burden can increase by the deterioration of dementia, as caregivers find that they must supervise a person more closely. Besides that, the person's cognition may change unpredictably during the day (from lucidity to confusion), making social relationships precarious (91).

In this review, we identified technology applications that contribute to lower the care burden of an informal caregiver of a person with dementia. These technologies for example use reminders to keep a daily rhythm or can give alerts and/or information due to a monitoring system that uses sensors. Furthermore, we also identified technologies ($N = 16$) that contribute to a lower care burden but also to improve sleep. These technologies are for example technologies that can be used to calm a person with dementia or can support a caregiver and/or person with dementia during the night with alerts or music/lights (see **Table 8**). Sensor-based technology such as waring systems as well as robot technology such as Tessa and Paro were found as well. One technology application is designed to lower the care burden and to have a positive effect on the reduction of social isolation of the person with dementia (in this case).

In regard to "improve sleep," robot-, sensor-, music- and lighting-based technologies were included. It is known that enough light during the day can improve mood and behavior, cognition, vision, and sleep (25, 92). These technologies can indirectly support sleep of persons with and/or without dementia. The robot included is regarding improved sleep is the seal Paro which is also included in lowering the care burden. (Music) Pillows can support people with dementia to calm down and fall asleep and sleep through.

Sleep is not always mentioned or measured specifically in the literature studies. Because sleep could be defined in the literature as part of the activities of daily living. So, for further research, it is important to define the daily activities and on which activities technology applications will contribute. In addition, it could also be mentioned as a side effect of other interventions. In other studies, improved sleep can be a side effect of other interventions.

This review had a focus on lowering care burden, improving sleep and reducing social isolation. In our opinion, a lower care burden and a higher sleep quality can contribute to reducing social isolation. However, for this review, we did not search on technology applications specifically focused on social contact even though that kind of technology is available. Khosravi et al. (93) identified eight different technologies that have been applied to reduce social isolation, namely general ICT, video game,

robotics, personal reminder information and social management system, asynchronous peer support chatroom, social network sites, telecare, and 3D virtual environment. However, the study was not focused on dementia care in home settings. To our knowledge, limited studies describe the use of technology applications that have a focus on care burden, lack of sleep, and social isolation of informal caregivers of people with dementia. Goodman-Casanova et al. (94) described a support, monitoring and reminder system and a television-based assistive service to use during the COVID-19 pandemic. Memory café online described by Masoud et al. (95) also arose due to COVID-19. A telehealth solution is mentioned by Kabir et al. (96), this solution is an application on a smartphone or tablet. With this application an informal caregiver gets support from peers and healthcare professionals. An easy-to-use telephone is described by Topo et al. (97), this kind of technology is also identified in our review.

Limitations of the Study

In this review, we did not differentiate between studies in home-settings and elsewhere even though some of the applications currently are only available for long-term care facilities, e.g., due to pricing or complexity of the technology. This was a contentious choice, as over time, these technologies may be used in the home environment therefore it is relevant to include these technology applications. For example, we know that the social robot seal Paro is also used individually. However, no studies reported about the use of Paro in home settings although this could be valuable and relevant. Technology applications developed for bigger settings are not always appropriate to install in the home-setting and cannot always be used independently, or the investment for an individual is too high. Besides this we do not take into account the cost-effectiveness and effectiveness of the technology applications included; in further research we can look at these aspects. Technology applications which are less suitable for use at home are for example dynamic lighting, Paro, Tooloba, AAL Sense Garden, AAL ReMIND, NAO, Kabochan, Bomy and Silverfit.

The identified technology applications are categorized on lowering the care burden, improving sleep, and decreasing social isolation, by the authors based on the description of these technologies. Moreover, the assignment to a category is, done on the four-eyes principal method (20). The Pyramid of Technology (18) was used to categorize the technology applications found. Discrepancies between authors concerning the place of the application on the level of Pyramid of Technology were solved by discussion until consensus was reached. The model helped to calibrate and determine the most appropriate classification of the status of the individual technology. In that way, the model provides insight into the status of the technology and helped to reach a consensus between researchers. The second and third authors labeled technology applications used and categorized these based on abstract only to calibrate with the scoring first author. Scoring based on abstract was sometimes difficult because of missing information regarding the specific technology. In addition to this, categorizing technologies by using this level of Pyramid of Technology directs categorization in one way only. Yet, this way was chosen because it provides insight into the level of development status of the technology applications in daily practice It is used to indicate the accessibility and usability to the aging population. Another limitation is that all authors are from The Netherlands so especially the technology applications from other sources and countries are incomplete due to limitations in the accessibility of other sources outside the Netherlands. Furthermore, the search ended in May 2021, other studies after May 2021 could therefore have not been included, because some technological developments are very fast, this can be seen as a minor limitation of the study.

Future Studies

This scoping review is part of a larger project regarding finding solutions to release the care burden of informal caregivers of people with dementia. The results of this first exploration will be discussed in one or more consultation rounds, according to Arksey and O'Mally (16) and Rumrill et al. (17). Further studies should also focus on the efficacy of the available technologies. In addition, we need to pay attention on how to achieve scaling up of technology applications for people with dementia, even beyond the use in healthcare.

CONCLUSION

This scoping review identified technology applications to support caregivers of persons with dementia. Several applications were found, however, most of the applications were located at the second level of the Pyramid of Technology, namely the operational level.

A diverse group of technology applications is available to support an informal caregiver of a person with dementia, in and around the night. The technology identified supports informal caregivers in different ways. Some targeting the person with dementia, others the informal caregiver or both. Technology applications were mostly used to lower the care burden of an informal caregiver by supporting daily rhythm, by calming a person with dementia, by increasing safety in the home, or supporting communication.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

CH determined the research and HK the method to analyze the data. CH performed data collection and preparation of the manuscript with support of HK and EH. The analysis and interpretation of the data was performed by CH, HK, and EH. All authors reviewed the results and approved the final version of the manuscript.

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Studies on the Digital Inclusion Among Older Adults and the Quality of Life—A Nanjing Example in China

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Digital inclusion can bridge the digital divide and reduce the social exclusion of older adults, yet it is understudied in China. This research examined factors influencing the digital inclusion of older adults in China and the relationship between digital inclusion and quality of life. Data collected from 312 older people ($M = 69.6$ years old) in Nanjing were included in a multinomial logit model to tackle these questions. Their attitudes toward technology were the most significant factor predicting their digital inclusion. Other factors included party affiliation, living situation, personal average monthly income, occupation, and capacity for instrumental activities of daily living (IADLs). This study shows digital inclusion has a direct impact on quality of life. It also serves as an intermediate variable that affects older people's attitudes toward technology and their IADL capacities. Most importantly, digital inclusion promotes social integration of older adults and improves the quality of their lives. Hence, it should not be ignored. Older people's attitudes toward technology are one of the keys to promoting their digital inclusion.

Keywords: digital inclusion, quality of life, multinomial logit model, older adults, Nanjing

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INTRODUCTION

The two great trends of our era are the internet and the aging of our population. The former is becoming a tool to cope with the latter and a means for building a smart aging society. Internet support can help improve services for older adults, effectively target their needs, and increase competencies for managing seniors (1). The internet has revolutionized the means of social participation among older people (2). It has also become a pathway for improving their physical and mental health and their sense of wellness and satisfaction.

However, a smart aging society will face many difficulties. The elderly may have lower economic status as China's economy, cost of living and income levels grew dramatically over the last 20 years. Some face the difficulties associated with declining strength and sensory functions, less access to technology and learning, and may be more risk averse. Compared with younger people, they are less likely to be exposed to digital information and communication technology (ICT). Thus, they are particularly vulnerable to missing out on the benefits of technology and finding themselves lost to the "digital divide." This problem should never be taken lightly. If left unattended, this could lead to a disconnect between older people and society (3). Closing the digital divide, reducing social exclusion through informatization, facilitating digital inclusion, and achieving greater inclusion in

a harmonious society have become important goals. However, the study of digital inclusion among older adults in China is in its infancy. This paper provides some initial responses to the following questions: what factors affect digital inclusion among older adults in China? Does digital inclusion of older adults play any role in their quality of life?

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Digital inclusion is the process of closing the digital divide (4). This means the "individual and community are free from barriers to access to information through information and communication technology, thereby effectively participating in every aspect of knowledge society and economic development, and obtaining social benefit according to their will and capacity" (5).

In empirical studies outside China, digital inclusion is closely related to many factors. The Multidimensional Explanatory Conceptual Model of Information Society Inequality proposed by De Haan (6) helps us clarify the levels and relationships among various influencing factors. On the basis of Rogers' innovation diffusion theory and Coleman's capital theory, combined with many previous empirical research results, De Haan classified the influencing factors of the digital divide into structural and individual factors and argued that these different dimensions did not act independently on individual IT access, but worked together to form uneven social, material, cognitive (i.e., human capital), and time resources (counted as a type of material resources), which ultimately led to unequal access to technology (6). Individual characteristics include age and generation, gender, ethnicity and race, intelligence, and personality, and opportunity structures, including family status, education system, and labor market.

Drawing on this multidimensional explanatory model of information society inequality, combined with the latest relevant studies in and outside China and the characteristics of the Chinese older adult population, we can reinterpret the influencing factors of digital inclusion of Chinese older adults from two perspectives: personal characteristics and opportunity structure.

Regarding personal characteristics, gender and age are the basic variables that have received more attention, and most studies found that gender differences are also prevalent among the older adult population, where men have higher intention to use the internet than women (7). Old-old adults are also more limited in their use of the internet due to a higher degree of physical decline than young-old adults (8); therefore, age may reflect its consequences, such as the impact of daily living abilities, and many studies have shown that health status is a key factor influencing internet use among older adults, with healthier older adults being more likely to use the internet (9). Older adults with impairments in vision, hearing, and finger dexterity are less likely to use the internet (10). In turn, all instrumental activities of daily living (IADLs) may also be supported by technology (11). Accordingly, the first hypothesis of this study is proposed.

H1.1: IADLs Are Positively Associated With Digital Inclusion

According to the Multidimensional Explanatory Conceptual Model, individual factors of ability such as intelligence and human capital would predict greater access to technology. In terms of structural characteristics, family, school, and workplace are often considered the context for accessing various resources. At the family level, for older adults, marital status and residential status (12) influence their internet use behavior through device and technical support. These two variables affect not only household possession and access to resources, but also the individual's ability to access technology resources and use support from the household. It has been shown that living with children or partner has a positive effect on older adults' learning to use the internet (12) and that widowed and divorced older adults use the internet significantly less frequently than unmarried and married groups (9). Accordingly, the following hypotheses were proposed.

H1.2: Marital Status Is Positively Related to Digital Inclusion

The Multidimensional Explanatory Conceptual Model would further present the next hypothesis on CPR-residence as residential status (12) influences device support and technical support.

H1.3: Coresident Living Situation Is Positively Associated With Digital Inclusion

The Multidimensional Explanatory Conceptual addresses education as a pathway to enhance digital skills, but it may also be a response to cognitive ability (antecedents) and occupation (consequences) for older adults born before the internet age (13). Still, a large body of research suggests that educational attainment is consistently associated with internet use behavior among older adults (13) and that older adults with higher educational attainment are more literate and will engage more in information-sending and news-reading activities (14). Therefore, the model supports the following hypothesis.

H1.4: Level of Education Is Positively Related to Digital Inclusion

Older adults in the non-networked generation are more likely to develop their ICT ownership and digital skills in the workplace. Not only is the workplace a key arena for individuals to develop their social networks, but it is also an important place to obtain material resources (e.g., income, electronic devices). The former implies that others in the social network can influence the purchase and use behavior of personal digital products by providing IT support, creating an atmosphere of acceptance of new products and reducing uncertainty about the purchase of new products (6). The latter influences the acquisition of personal digital products; occupations with higher social status are more likely to have access to the internet that provides access to a wealth of information. Some studies have shown that older adults who engaged in physical and mental labor before retirement

differed significantly in terms of the difficulty of learning to use the internet, their intention to use it, and the length of time spent online (15). In addition to the binary division between physical and mental labor, party membership is also usually associated with higher socioeconomic status in China, and these individuals have unique advantages in terms of career advancement and expanding their network resources, especially those with cadre status, and as such, these older adults perform better in terms of using new media technologies (16). The following hypothesis is therefore proposed.

H1.5: Retirement From Occupation Is Negatively Associated With Digital Inclusion

Given the importance of party affiliation to access to community resources, the Multidimensional Explanatory Conceptual Model would predict the added Social Capital and structural advantages of being engaged in party-sponsored events would positively affect access to technology (6).

H1.6: Party Affiliation Is Positively Related to Digital Inclusion

Although income, education level, and occupation are seen as three important variables for measuring socioeconomic status and there are correlations among the three, income still has an independent role after controlling for the education variable, due to the fact that economic factors mainly govern older adults' ability to purchase equipment and maintain its operation, which is closely related to whether they use the internet (17). However, some scholars have argued that income is not related to ICT use among older adults (18). Therefore, we examined income as well and proposed the following hypothesis.

H1.7: Personal Average Monthly Income Is Positively Associated With Digital Inclusion

We examined both these personal characteristics and opportunity structure factors in the context of basic demographic variables. In addition, the rational behavior model suggests that attitudes are the positive or negative feelings that people have about engaging in a target behavior and are determined by their primary beliefs about the outcome of the behavior and their estimates of the importance of that outcome. An individual's behavioral intentions are influenced by behavioral attitudes, and attitudes ultimately have a large impact on individual behavior by acting on behavioral intentions. Positive or negative attitudes toward technology and its consequences also are an important reason for the digital divide among people, because attitudes are the combined result of the interaction of factors such as the uneven geographical development of ICT technologies, individual personalities, socioeconomic activities, demand for the internet, and product characteristics (19–21). Many empirical studies have also shown that positive attitudes toward digital technologies in the age of consultation and networking increasingly affect the normal functioning of life and that lack of interest can be considered a barrier to access to resources, participation in the community, and a cause of the digital divide among people (16, 19). Therefore, we incorporated the consideration of attitudinal elements and proposed the following hypothesis:

H1.8: Older Adults' Positive Attitudes Toward Technology Are Positively Associated With Digital Inclusion

International studies have proven the positive effect of digital inclusion on older people's physical, mental, and spiritual wellness. Learning about and using ICT and the internet can improve older people's cognitive ability (22); enhance their relationships with family and friends; reduce their sense of loneliness (23); strengthen their sense of self-efficacy (24), independence, and self-growth; and promote their social integration (24). These all increase their community satisfaction (18) and quality of life (25). Studies of older Chinese people and the relationship between digital inclusion and their quality of life is relatively lagging. To study these issues, we proposed another set of hypotheses. This second set of hypotheses involved the relationship between the digital inclusion of older adults and their quality of life.

Hypothesis 2: Digital Inclusion of Older Adults Affects Their Quality of Life

Among factors that may affect the quality of life of older adults, scholars have paid extensive attention to basic demographic variables such as gender, age (26), income (27), region, occupation (28), education level (29), marital status (30), living status (31), and physical and mental health (32), proving that they are closely related to quality of life in old age. Therefore, this study incorporated some of the key factors in Hypothesis 1 as control variables to more clearly observe the independent effect of digital inclusion.

The theoretical framework of the study is shown in **Figure 1**.

METHODS

Sampling and Data Collection

Nanjing was selected as the survey site because it is an important city with the dual characteristics of being a "digital city leader" and "aging society." On one hand, Nanjing's population of adults aged 60 or older reached 10.04% of the total population as early as 1990, indicating that Nanjing has become an aging society. According to the latest census results, the population aged 60 or older in Nanjing accounted for 18.98% of the total population in 2020, an increase of 5.23% compared with 2010, and the population aged 65 or older accounted for 13.70%, an increase of about 4.52% (33). The aging of the population in Nanjing is showing a continuous acceleration, which means that Nanjing has been and will be an aging society for a long time (34). On the other hand, as early as 2006, when the State Council issued the 2006–2020 National Informatization Development Strategy, Nanjing proposed the goal of building a "digital Nanjing." In recent years, the production and sales rate of electronic products in Nanjing has been high, and

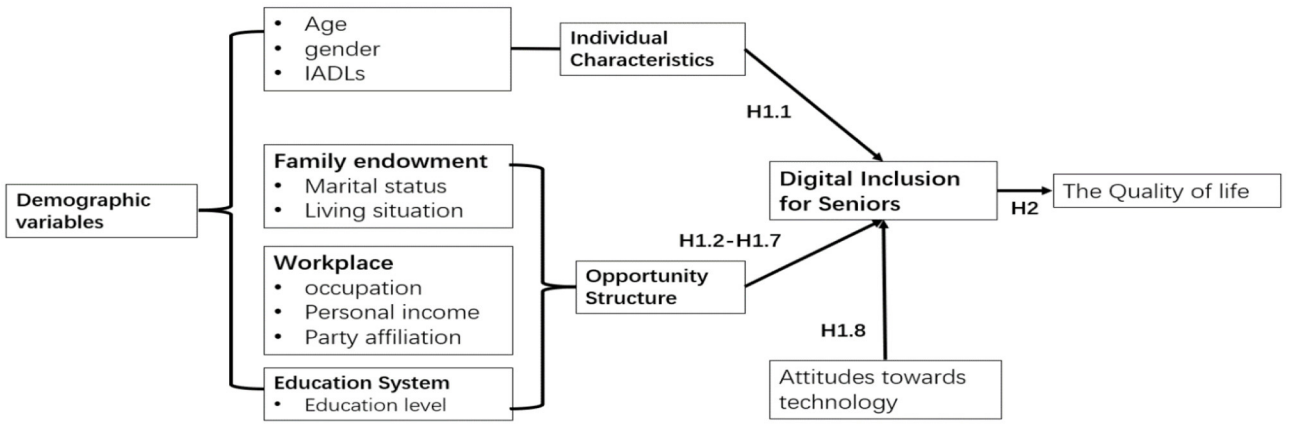

FIGURE 1 | Theoretical framework of this study.

the manufacturing industry of communication equipment, computers, and other electronic equipment has maintained strong growth. This rapid informatization has attracted many smart pension projects to be stationed and implemented there. Nanjing has outstanding advantages nationwide in both the information and communication industry and the development of the "internet add pension industry," and it is a pioneer of smart city construction (35). This research focused on adults aged 60 or older in Nanjing as its survey participants.

Due to the survey's many questions and the challenges they posed to older people, the survey staff assisted the respondents if they needed help. Interviewers were recruited from among postgraduate students in social work and anthropology with survey experience. The study team provided systematic training on the questionnaire survey for the interviewers before the investigation began. The selection of study objects followed the principle of simple random sampling, stratified sampling, and systematic sampling methods. The process was as follows: (a) Random communities in Nanjing were selected; they were Mufu Community, Jiangwan Community, Baota Community, and Jinling Community. (b) The communities were categorized according to their economic status (public budget revenue and disposable income per capita) and geographic location—either downtown or not downtown community (city suburb). Of the four communities selected, three—Mufu, Jiangwan, and Baota—were in the downtown communities of Gulou and Jianye. Jinling is in the city suburb of Qixia. According to data from the *Information of the Senior Population and Report on the Development of Elderly Affairs in 2017 in Nanjing* by Nanjing Bureau of Civil Affairs, the calculated ratio of the older adult population in downtown to that in the city's suburbs is approximately 2:3. (c) Based on the general city-to-suburb ratio of the older adult population (2:3), equidistant sampling was conducted with the stratified sampling frame of residents aged 60 or older in the four selected communities. Based on the equidistant sampling, participants with the following criteria were excluded from the study: those unable to participate in the interview due to health conditions; those who did not currently live at their residential address in the community and whose current address was relatively far away; those whose spouses had been selected as participants; and those who declined to participate in the interview. (d) Given the difficulties of equidistant sampling, maximum effort was made to make the downtown-to-suburb ratio of the sample close to the real ratio. Of 350 questionnaires distributed, 341 were returned, of which 312 were valid. The number of valid responses met our expectations. The basic information of these survey subjects is shown in **Table 1**.

Measurement

According to our study's needs, the following content was included in the questionnaire: the table of digital inclusion and questions regarding the respondent's attitude toward the internet and information technology products, quality of life, health condition, and personal information. Among these inquiries, the respondent's attitude toward the internet and information technology products involved their "opinions on the internet" and "attitude toward products of information technology"; physical condition included disability status and capacities for IADLs; and personal information included social characteristics of gender, age, hometown, party affiliation, level of education, marital status, living situation, occupation, years of residence in the area, number of children, household monthly income, monthly income per capita, etc. The questionnaire was developed based on a questionnaire used by the research team of the University of Hong Kong in the study of digital inclusion in Hong Kong (36), which has been used in research in Shanghai with good reliability and validity (37, 38). The operationalized description of the key variables is as follows.

Digital Inclusion

The research team of the University of Hong Kong, which studied digital inclusion in Hong Kong with a sample of 2,596 participants including vulnerable groups (36), collected firsthand information regarding four dimensions of ICT:

TABLE 1 | Basic information of survey subjects.

Variable	Category	Number of people	Percentage	Cumulative percentage
Age	60–65	96	30.9%	30.9%
	66–70	99	31.8%	62.7%
	71–75	61	19.6%	82.3%
	76 and above	55	17.7%	100.0%
Gender	Female	180	57.9%	57.9%
	Male	131	42.1%	100.0%
Party	Non-partisan	201	68.6%	68.6%
affiliation	Member of a political party	92	31.4%	100.0%
Marital status	Unmarried	57	18.7%	18.7%
	Married	248	81.3%	100.0%
Living	Older adult living alone	32	10.5%	10.5%
situation	Older adult not living alone, not with young people living at home	155	51.0%	61.0%
	Older adult not living alone, with young people living at home	117	38.5%	100.0%
Level of education	Primary school and below (including illiterate)	74	23.8%	23.8%
	Junior high school	101	32.5%	56.3%
	High school and above	87	28.0%	84.3%
	Collage and above	49	15.8%	100.0%
Occupation	Manual labor	111	37.9%	37.9%
(current/before retirement)	Non-manual labor	182	62.1%	100.0%
Personal	Below 2,000	35	11.5%	11.5%
average	2,000–2,999	53	17.4%	28.9%
monthly	3,000–3,999	148	48.5%	77.4%
income	4,000 and above	69	22.6%	100.0%
Attitude	Negative	52	23.6%	16.7%
toward technology	Positive	168	76.4%	54.0%
IADLs		Average value 23.63		

TABLE 2 | Hierarchical regression analysis.

	Variable	Step one	Step two	Step three
Step one	**Personal characteristics**			
	IADLs	0.269*	0.207	0.128
Step two	**Opportunity structure**			
	Marital status		0.096	0.036
	Living situation		−0.216	−0.003
	Occupation (current/before retirement)		0.167	0.123
	Party affiliation		−0.029	0.067
	Personal average monthly income		0.261*	0.100
	Level of education		0.092	0.021
Step three	**Attitude toward technology**			0.479***
	F	5.790*	2.969**	5.155***
	R^2	0.073	0.234	0.381
	ΔR^2	0.060	0.155	0.307

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

availability, affordability, usage, and knowledge level. They also established a comprehensive digital inclusion index. This was the first attempt among similar research efforts in China and around the world. It was also the starting point for further discussions of the digital divide. This study adopted this comprehensive digital inclusion index and made minor adjustments according to the situation of Nanjing respondents before data collection—for example, "percentage of elderly people who have used www.e123.hk." Because this website is unique to Hong Kong, it was not suitable for mainland older adults to answer, and there was no equivalent website relevant to mainland China; thus, this question was removed in this study. The final table of measurements for our study included 15 indicators assessed via 17 questions; of which, two were follow-up questions if the respondent selected a certain option. The survey measured dimensions including internet access and usage, internet knowledge and skills, etc. Referring to the calculation method of the European Union, the ultimate personal value of digital inclusion was the average of all indicators.

Quality of Life

Among the various scales measuring the quality of life of older adults, CASP-19 is a widely used tool (39). It is a Likert scale of 19 questions developed to examine the status of older people in the United Kingdom. It has four domains: control, autonomy, self-realization, and pleasure. CASP-19 and its simplified versions, CASP-14 and CASP-12, have shown relatively high applicability in Europe, Taiwan, and mainland China (39). This study used revised quality of life scale for older adults created in 2009 (CASP-14), which features 14 sentences describing life or feelings about life (40). Scores were based on the four response options of "often," "sometimes," "rarely," and "never." The value for each question ranges from 1 to 4 points, and the final quality of life index is the average score of all dimensions.

Other Key Independent Variables

The operationalization of other key variables included: (a) Marital status, which involved the influence of spouses on the internet use of older adults and was coded as "married" or "unmarried" (single, widowed, divorced, or separated). (b) Living situation, which involved the influence of children on the digital inclusion of older adults: "living alone" (no young people in the home) and "not living alone" (young people in the home). (c) Level of education, which was divided into primary school and below, junior high school, high school or beyond, or college or beyond—colleges, universities, and postgraduate studies were merged into one type because higher

TABLE 3 | Final model statistics of digital inclusion.

	B	SED	Beta	*T*	*P*	Tolerance	VIF
(Constant)	0.241	0.245		0.986	0.328		
IADLs	0.012	0.010	0.128	1.255	0.214	0.889	1.125
Marital status	0.013	0.048	0.036	0.275	0.784	0.546	1.831
Living situation	−0.001	0.027	−0.003	−0.020	0.984	0.480	2.083
Occupation (current/before retirement)	0.033	0.028	0.123	1.156	0.252	0.818	1.222
Party affiliation	0.018	0.030	0.067	0.588	0.558	0.719	1.390
Personal average monthly income	0.015	0.016	0.100	0.909	0.367	0.762	1.312
Level of education	0.003	0.017	0.021	0.185	0.854	0.689	1.452
Attitude toward technology	0.163	0.041	0.479	3.988	0.000	0.641	1.560

Durbin-Watson: 1.651; $F_{(75)} = 5.155$, $P < 0.001$.

TABLE 4 | Regression analysis of influencing factors of quality of life.

Model 2.1	B	SED	Beta	*T*	*P*	Tolerance	VIF
(Constant)	−0.519	0.978		−0.531	0.597		
Marital status	0.083	0.195	0.056	0.428	0.670	0.603	1.659
Living situation	0.028	0.108	0.037	0.262	0.794	0.533	1.876
IADLs	0.061	0.042	0.164	1.433	0.156	0.799	1.252
disability status	0.260	0.175	0.166	1.483	0.143	0.828	1.207
Attitude toward technology	−0.224	0.152	−0.181	−1.480	0.143	0.694	1.441
Digital inclusion	1.757	0.457	0.460	3.849	0.000	0.730	1.371

Durbin-Watson: 1.670; $F_{(76)} = 4.313$, $P = 0.001$.

education was not widely popularized in the 1940s and 1960s, when most of the current older adults were educated, and most college education referred to junior college (15). (d) Occupation before or during current retirement, which follows the method of Jiao (41). Considering that the occupational dispersion of middle-aged and older people in China is not very large, if occupations were divided into more types, it would lead to many empty cells, which may have affected the results of model estimation. Therefore, occupations were divided into two categories: manual labor, including farmers and workers, and non-manual labor, including management, professional and technical, office, and business service personnel. (e) Party affiliation, which refers to membership in the Communist Party of China and was treated as a yes-or-no dichotomous variable. (f) Economic level, in which those whose per capita annual household income was less than half of the sample median were considered to be in poverty—the "personal average monthly income" variable determined the approximate boundary of each group based on quartile, so that the population in each group was relatively evenly distributed. (g) Attitudes toward technology: this study used a self-assessment method, asking respondents to comprehensively describe their attitudes toward ICT technology. Samples containing positive words like "satisfied," "support," and "like" or neutral words like "double-edged sword" were coded as "positive attitude." Negative responses such as "dissatisfied," "unsupported," "do not understand," and "can't learn," were coded as "negative attitude."

STATISTICAL METHODS

Each hypothesis was tested based on the level of measurement of the variables. Methods included correlation, ANOVA, independent samples T test, and multiple regression to determine the direction of the relationship of each independent variable with digital inclusion.

RESULTS

Exploration of the Influencing Factors of Digital Inclusion

This set of hypotheses concerned the effect of basic demographic variables on digital inclusion in older groups. The tested variables were age, gender, IADLs, marital status, living situation, education level, current and preretirement occupation, party affiliation, personal average monthly income, and attitudes toward technology.

The independent variables and their relationship with digital inclusion were examined individually. Two methods were used: analysis of variance or independent-samples *t*-test. The independent variables related to the dependent variable were introduced into the multiple regression model to test whether the model could predict the relationship between the variables as hypothesized.

After exploring all potential independent variables and their relationship with digital inclusion one by one, we found party affiliation ($p < 0.01$), living situation ($p < 0.05$), education level (p

TABLE 5 | Hierarchical regression analysis of quality of life and digital inclusion.

	Variable	Model 3.1	Model 3.2
Step one	**Demographic variables**		
	Marital status	0.162	−0.086
	Living situation	−0.069	0.050
Step two	**Digital inclusion**		0.320**
	F	1.169	4.520**
	R^2	0.021	0.112
	ΔR^2	0.003	0.087

**$p < 0.01$.

< 0.01), personal average monthly income ($p < 0.01$), occupation ($p < 0.01$), IADLs ($p < 0.05$), and attitudes toward technology ($p < 0.01$) all had significant correlations with different levels of digital inclusion.

Multiple regression analyses of the independent variables related to digital inclusion were conducted to explore explanatory models of dependent variables. The recommended model for multiple regression analysis is as follows.

Digital inclusion is a linear function of education level, party affiliation, living situation, personal average monthly income, occupation, IADLs, and attitudes toward technology.

To ensure an optimal model of multiple linear regression analysis, hierarchical regression analysis was warranted to explore the contribution of each variable to the explanation of the dependent variable. The seven independent variables were put into the model in three steps: (a) demographic variables, including education level, party affiliation, living situation, personal average monthly income, and occupation; (b) IADLs; and (c) attitudes toward technology. The third model had the strongest power, explaining 31.9% of the variance in digital inclusion. The test results are shown in **Table 2**.

Model 1.1, in which only one factor representing personal characteristics, IADLs, was introduced, was significant ($\Delta R^2 = 0.060$). This shows that digital inclusion was positively influenced by IADLs and the effect was significant. The higher the average monthly income of the individual, the higher their digital inclusion.

Model 1.2 introduced variables representing the three dimensions of opportunity structure, which increased the explanatory effect of the model regarding digital inclusion to 15.5% and was statistically significant. When these variables were added, only personal average monthly income had a significant positive effect on the dependent variable, and IADLs were not statistically significant in the model. Nevertheless, IADLs in Model 2 played a role in digital inclusion.

In Model 1.3, all predictor variables were used simultaneously. The multivariate regression coefficient was 0.617 ($R^2 = 0.381$) and adjusted R^2 was 0.307, implying that the three categories of individual characteristics, opportunity structure, and attitudes toward technology together explained 30.7% of the variance in digital inclusion. Among all predictor variables, the *t*-test of the unstandardized regression coefficient (*b*) of the newly added "attitudes toward technology" variable shows that it contributed to competence in digital inclusion. This indicator contributed most of the explanatory power ($b = 0.163$, $\beta = 0.479$, $t = 3.988$, $p < 0.001$), suggesting it is a critical variable for digital inclusion. The more an older adult held positive attitudes toward technology, the higher their digital inclusion.

Therefore, digital inclusion among older Chinese people is a linear function concerning level of education, party affiliation, living situation, personal average monthly income, occupation, IADLs, and attitudes toward technology.

As shown in **Table 3**, the result of the analysis of variance was $F_{(75)} = 5.155$, $p < 0.001$, indicating the integration of all indicators effectively predicted digital inclusion. The hypothesis of linear distribution, normal distribution error, and uncorrelated error were properly tested and considered. Judging from inclusion (>0.10) and variance inflation factor (<5) values, these related variables did not produce collinearity problems. In the final model, the introduction of attitudes toward technology reduced the effect of personal average monthly income, a variable of statistical significance, on digital inclusion. Thus, in the complete model, demographic variables had no influence on the dependent variable. Attitudes toward technology played a major role and positively correlated with digital inclusion. Other variables played a role based on attitudes toward technology.

Relationship Between Digital Inclusion and Quality of Life

The second set of hypotheses primarily examined the relationship between digital inclusion of older adults and their quality of life.

Predictor variables significantly related to the quality of life were incorporated to conduct a multiple regression analysis. Demographic variables significantly related to the quality of life of older adults included living situation, $F_{(292)} = 4.926$, $p = 0.008$, and marital status, $t = -4.146$, $p < 0.01$. In addition, digital inclusion, $r_{(116)} = 0.322$, $p < 0.001$; disability status, $t = -3.438$, $p = 0.001$; attitudes toward technology, $t = -3.365$, $p = 0.001$; and IADLs, $r_{(296)} = 0.334$, $p < 0.001$, all had correlations of different levels of significance with the dependent variable.

Multiple regression analysis was performed on these variables related to quality of life to explore the explanatory model of the dependent variable. The recommended model after multiple regression analysis is as follows.

Quality of life is a linear function of marital status, living situation, IADLs, disability status, attitude toward technology, and digital inclusion.

In this model as shown in **Table 4**, the tolerance of each variable was greater than 0.10, the VIF was <5, and the Durbin-Waston index was 1.670, indicating no serious collinearity problem. The analysis of variance of the model was $F_{(76)} = 4.313$, $p < 0.005$, indicating the combination of independent variables could effectively predict the quality of life of older adults.

As the results show, when all predictors were used at the same time, the multiple regression correlation coefficient (*r*) was.520 ($R^2 = 0.270$) and the adjusted R^2 was 0.207. That is, all independent variables together explained 20.7% of the variation in quality of life. Among the predictors, only digital inclusion ($p < 0.001$) was statistically significant when acting

together with the rest. Its beta value was the largest among all independent variables, i.e., digital inclusion contributed most of the explanatory power to the prediction of quality of life. The higher the digital inclusion of older adults, the higher their quality of life. The other indicators enhanced, to a certain degree, the significance of the overall model.

Therefore, does digital inclusion significantly explain quality of life? Regression analysis was performed to test Hypothesis 2.

Digital inclusion alone was very significant, $F_{(115)} = 13.196$, $p < 0.01$, $\Delta R^2 = 0.096$, in predicting quality of life. The unstandardized regression coefficient ($b = 1.209$) shows that for every 1-unit increase in digital inclusion, the quality of life of older adults increased by 1.209 units. The regression coefficient should be equal to the slope of its best-fitting model. The R^2 value shows digital inclusion explained 9.6% of the variation in quality of life.

To further clarify the actual effect of digital inclusion on the quality of life of older adults, some demographic variables significantly related to quality of life in this study were then included as control variables to conduct a hierarchical regression test. Demographic variables that acted as control variables included living situation, $F_{(292)} = 4.926$, $p = 0.008$, and marital status, $t = -4.146$, $p < 0.01$.

Statistics show, after controlling for variables, digital inclusion had a significant, positive correlation with the quality of life of older adults ($\beta = 0.320$, $p = 0.001$). The higher the digital inclusion of older adults, the higher their quality of life. The overall model was significant, $F_{(111)} = 4.520$, $p = 0.005$, and 8.7% of the variation in quality of life can be ascribed jointly to digital inclusion and demographic variables. Yet when acting together, demographic variables had little effect on the quality of life and were not statistically significant. Only digital inclusion played a major role in the quality of life. Hypothesis 2.2 was thus verified. See **Table 5** for details of data.

In addition, through the hierarchical regression analysis of influencing factors of quality of life, we found the introduction of digital inclusion caused a decrease in the beta value of two variables: attitudes toward technology and capacity for IADLs. This suggests digital inclusion may have a mediating effect on the quality of life.

In this study, the attitude toward technology and IADLs were important factors in the mental wellness and physical health of older adults, respectively. The internet plays a key role in promoting people's social connections and strengthening social support networks. Digital inclusion, therefore, is considered an important method to bring in social support. After reviewing the literature, we found the relationship among psychological factors, health status, social support, and quality of life is complex and the influential mechanisms of the first three variables on quality of life varied.

To further explore the mediating effect among digital inclusion, attitudes toward technology, and quality of life, further hypotheses were proposed based on our literature review:

Hypothesis 3.1: Digital inclusion is a mediator between attitudes toward technology and quality of life.

Hypothesis 3.2: Attitudes toward technology is a mediator between digital inclusion and quality of life.

Hypothesis 3.3: Digital inclusion is a mediator between IADLs and quality of life.

The three-step regression showed digital inclusion was a mediator between attitudes toward technology, IADLs, and quality of life.

Specifically, digital inclusion had a full mediation effect between attitudes toward technology and quality of life; attitudes toward technology predicting quality of life: $\beta = 0.274$, $p < 0.01$; attitudes toward technology predicting digital inclusion: $\beta = 0.138$, $p < 0.01$. Attitudes toward technology and digital inclusion jointly predicted quality of life; digital inclusion: $\beta = 1.175$, $p < 0.01$; attitudes toward technology: $\beta = -0.094$, $p = 0.519$. This shows the attitudes of older adults toward technology affected their quality of life by influencing digital inclusion.

Digital inclusion mediated between IADLs and quality of life; IADLs predicting quality of life: $\beta = 0.124$, $p < 0.01$; IADLs predicting digital inclusion: $\beta = 0.023$, $p < 0.05$. IADLs and digital inclusion jointly predicted quality of life; digital inclusion: $\beta = 1.127$, $p < 0.05$; IADLs: $\beta = 0.082$, $p < 0.05$. This test shows some aspect of IADLs had an indirect impact on quality of life through digital inclusion, whereas the other part had a direct impact on the quality of life.

DISCUSSION AND CONCLUSION

This study found that the degree of digital inclusion was affected by six factors, including party affiliation, living situation, personal average monthly income, occupation, IADLs, and attitudes toward technology. Attitudes toward technology accounted for a large proportion of the explanatory power of the model of digital inclusion, indicating that these attitudes are an important variable affecting the digital inclusion of older adults. This is similar to the findings of Correa and Pavez (19). One possible reason is that older adults who have a positive attitude toward technology are more interested in ICT and conduct activities through the internet more frequently. Today, older adults generally have fear and anxiety when facing technology products, so their attitude toward technology has a particularly significant impact on their digital inclusion.

In addition, digital inclusion significantly contributed to quality of life; when combined with variables such as demographic variables and attitudes toward technology, it still contributed most of the explanatory power to quality of life, and the impact was significant. This study also found that digital inclusion is a mediator that affects quality of life through older people's attitudes toward technology and capacity for IADLs. Older adults' attitudes toward technology affected their digital inclusion, whereas digital inclusion affected their quality of life. The capacity for IADLs of older adults played a role in their quality of life through digital inclusion, and it directly affected their quality of life in certain aspects. This is similar to the findings of Damant et al. (42), who found that healthy older people were more likely to benefit from ICT services and that ICT had a significant impact on their quality of life. More studies have shown that the physical health of older adults is the primary factor affecting their quality of life (43). These results are

similar to those of the outcome analysis of mediation effects in our study.

Regarding the analysis of the impact of digital inclusion on quality of life, many domestic and foreign studies have drawn similar conclusions, proving that ICT can effectively improve the quality of life of older adults in different dimensions, including cognitive ability, social integration, and community satisfaction (18, 22, 24, 44), and these benefits seem to be related to developing a network of support from the internet (45, 46). The internet promotes communication between older adults and family, relatives, and friends; reduces loneliness; and enhances self-efficacy (24). It plays a role in social bonding, creating a connection between their world (where they are fairly isolated) and their family (including grandchildren), thereby effectively improving their quality of life (47). ICT has proven to be a new resource in both logical speculation and empirical research, and possession of digital resources yields independent and significant advantages in many fields (6). But is this advantage only strengthening the social capital of older adults in an advantageous socioeconomic position, thereby expanding the original social inequality, or is it compensating for the social capital of disadvantaged older groups and helping reduce social exclusion? There is no unified conclusion in the academic world. However, this study gives us a very important hint that in today's world of "active aging," digital technology is becoming an important medium for creating an excellent environment that supports older living and a social climate that promotes healthy aging. In the process of technological progress and social development, inclusion of the older adult population should be promoted.

Therefore, ICT has become a new pathway for wellbeing among older adults. In previous studies, factors affecting their were roughly divided among demographic, family, cultural, economic, and social domains. Of those, social factors mainly consisted of social capital, social support, social participation, socioeconomic status, etc. They were interconnected and interacted with each other. All had a significant impact on older adults' quality of life. The positive effect of having a social network and social support are particularly prominent. With the information age, the internet has rapidly become a means of stabilizing and broadening social connections that strengthen social support. However, older adults are "digital refugees"; they are on the wrong side of the digital divide. This is hindering the possible improvement of their quality of life. Previous studies have revealed quality of life can be improved, and social support provided through modern tools should not be brushed aside. Digital inclusion is now an important carrier for older adults. For certain groups, it has supplanted traditional social factors that affect quality of life. It has become a new way to promote the social integration of older adults.

As this study reveals, attitudes toward technology are an important consideration. Changing those attitudes may become a key breakthrough to promoting digital inclusion. The perceived usefulness and perceived ease of use factors in the technology acceptance model provide perspective on the causes of older adults' negative attitudes toward technology. Strategies to overcome such attitudes can be categorized based on micro and macro policy paths. The latter could include establishing a community for the development of the eldercare service industry and focusing on age-friendly designs to improve the ease of use of these products. Community-based digital training services could help eliminate technology fears and promote social connection. Subdividing the demand market of older adults could lead to enhancing users' perceptions of the usefulness of the internet while paying attention to the special needs of vulnerable populations. Lowering the threshold for the use of information technology products could create a safe and green internet environment. Micro paths could include social workers providing digital training through new media teaching. As the objects of digital inclusion, older adults must have the right attitude to overcome their social exclusion. Their children must take a positive view of their potential to accept new things and become a strong backup for their use of technology products.

From a theoretical perspective, by establishing a localized digital inclusion measurement system, attitudes toward technology can be considered an influencing factor. Concerning internal connections among the digital inclusion of older adults, social networks, support, capital, and other factors, and how they jointly affect older adults' quality of life, are important Research Topics for further study.

Digital inclusion is assumed to be a good thing. Older adults who choose to stay away from the internet and technology will not be easily integrated into our rapidly evolving society. They risk a declining quality of life as the times leave them behind. Currently, older adults who do not know how to use internet technology products and services may have higher life satisfaction. This is likely because we are still in the process of moving toward a world of digital inclusion. The negative effects of having no access of technology are not yet absolute. With the advance of digital inclusion in a highly developed information age, measures must be taken to facilitate the information acquisition and social participation of these digital refugees. If nothing is done, the digital divide will become larger, affecting even social equity and the stability of society. We must actively pay attention to this issue. China vigorously promotes digital inclusion through public policy. By discussing a specific population, we can see digital inclusion in more detail. It is possible to look forward to a future in which digital connectivity joins different populations, regions, and industries and the digital divide is eliminated as much as possible.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethical Committee of School of Social Development

and Public Policy in Fudan University. The participants provided their written informed consent to participate in this survey.

AUTHOR CONTRIBUTIONS

HY, HongtC, TP, and YL wrote the first draft. HonglC and YZ conducted the data collection and data analysis. All authors made revisions to the final manuscript.

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Social Support, Sense of Belonging, and Communication Technology Use Among Paid and Unpaid Caregivers of Middle-Aged and Older Adults

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Objectives: The objectives of this study are to: (1) describe communication technology use among paid and unpaid middle-aged and older caregivers of adults 50 and older in a natural (non-experimental) setting; and (2) examine the association between communication technology use, perceived social support, and sense of belonging in this population.

Methods: Means and standard deviations, or frequencies and percentages, were used to describe study participants. Chi-square tests or independent sample *t*-tests were used to compare sociodemographic characteristics, communication technology use, perceived social support, and sense of belonging to the local community between paid and unpaid caregivers. Multivariable regression analysis was performed to predict each outcome (i.e., sense of belonging and social support) based on the use of texting or communication applications.

Results: The average age of participants was age 64.2 years, and the majority was female (74.8%) and non-Hispanic White (66.9%). Compared to paid caregivers, unpaid caregivers were older (64.5 vs. 62.2 years, $p = 0.022$) and a larger proportion were non-Hispanic White (70.8% vs. 47.7%, $p < 0.001$). Nearly 83% of the study participants reported using texting or communication applications (81.5% among paid caregivers and 83.1% among unpaid caregivers, $p = 0.718$). After adjusting for caregivers' age, sex, race/ethnicity, and education, a significantly higher sense of belonging was observed among paid caregivers than unpaid caregivers ($b = 9.40$, $p = 0.009$). After adjusting for caregivers' age, sex, race/ethnicity, and education, the use of texting or other communication applications significantly increased caregivers' perceived availability of social support ($b = 0.35$, $p = 001$).

Conclusions: These study results showed a greater sense of belonging to the local community among paid caregivers compared to unpaid caregivers. The use of communication technology was associated with an increased sense of belonging to their local community among paid caregivers, yet the use of communication technology did not contribute to feelings of belonging among unpaid caregivers. In an aging society,

both paid and unpaid caregivers are essential elements of the care system. Research is needed to understand the social support needs of paid and unpaid caregivers and the types of interventions to promote social support and community engagement for both groups.

Keywords: communication technology, social support, sense of belonging, caregiving, older adult

INTRODUCTION

Over 40 million Americans are estimated to provide unpaid care to a family member or friend aged 50 years or older in 2020 (1). On average, unpaid caregivers for older adults provide over 22 weekly hours of care, and they assist their care recipients with basic and instrumental activities of daily living and medical tasks, as needed (1). Consistent evidence shows that informal caregivers have reduced social activities over time, which increases caregiver burden and negatively influences caregivers' health and quality of life (2–4). In addition to unpaid or informal caregivers (e.g., family members and friends), paid caregiving services are increasingly needed and more prevalent among care recipients of older ages.

Through social networks and interactions, caregivers can access social support in the form of emotional, informational, and other tangible and intangible resources. Social support can protect caregivers against feeling burdened (5) by providing resources to eliminate or reduce the perceived stress and alleviate the impact of stressors (6, 7). Having a sense of belonging, which is closely associated with perceived social support (8), can act as a buffer against caregiving burden and protect caregivers' mental and social well-being (9–11). Sense of belonging is described as a "component of connecting one's self into the fabric of surrounding people, places, and things" (12). While feelings of belonging have been investigated among various populations (e.g., young adults, older adults, and patients) (9, 13, 14), limited studies have examined the sense of belonging felt by caregivers. Furthermore, paid and unpaid caregivers may have different needs, preferences, and barriers related to connecting with their community and interpersonal groups; however, limited studies have examined or compared feelings of social support or sense of belonging among paid and unpaid caregivers (15).

Communication technologies can be a useful tool to connect caregivers to their social networks and enable them to access resources (16, 17). Specifically, this study focuses on communication technologies (e.g., texting and virtual communication applications), which are considered promising tools to mitigate social isolation among older adults (18, 19). According to Zwingmann et al. (20), family caregivers' perceived social isolation can be alleviated through caregiver support groups established in a more flexible and private setting, such as telephone- and internet-based communications. However, only 7% of informal caregivers of older adults use the communication technology to connect with other caregivers (1). Little is known about use of communication technology among caregivers, especially among paid caregivers, and its association with their social well-being in a natural (i.e., non-experimental) context. Furthermore, the majority of older adults' caregivers are older adults, and despite the increasing communication technology use among the older adult population, it has been suggested that older adults may only be using a few features of communication technologies (21).

This cross-sectional survey study aims to describe communication technology use among paid and unpaid, middle-aged and older caregivers of adults 50 years and older. This study also examines the relationship between communication technology use and perceived social support and sense of belonging to local communities among paid and unpaid caregivers of middle-aged and older adults. Intuitively, we hypothesized communication technology use to be positively associated with social support and sense of belonging to the local community among both paid and unpaid caregivers by facilitating social interactions and increasing their access to social support. Acknowledging the importance of both paid and unpaid caregivers in the system of care for older adults, this study included both caregiver types. This study further explored potential differences in the association between the communication technology use and social support and sense of belonging between paid and unpaid caregivers. Given the subtle differences in their caregiving contexts (e.g., training and work expectations for technology use), paid and unpaid caregivers may use communication technology differently for connecting with their local community or accessing social support.

METHODS

Data

This study utilized cross-sectional Qualtrics panel survey data collected from adult caregivers of middle-aged and older adults in November 2019. To be eligible to participate in the survey, one must be 18 years and older, be paid or unpaid caregivers of at least one middle-aged and older adults (50 years and older) who lived in a home environment. Quota sampling was used to ensure inclusion of diversity in the study sample (22). The quotas were applied in terms of regions (Northwest, Midwest, West, and South), gender, age, and race/ethnicity (maximum 60% non-Hispanic White) to resemble the adult caregiver populations. Among the overall respondents ($N = 626$), this study was limited to middle-aged and older caregivers ($n = 504$) because a larger proportion of middle-aged and older adults provide care for adults 50 years in the US, and less is known about communication technology use in this age group, despite its increasing availability uptake. Paid and unpaid caregivers are distinct caregiver populations, and communication technology may play different roles for social support and connecting them

with their local communities. This study included both paid and unpaid caregivers to provide greater understanding about the social support needs of both groups. The study was reviewed and approved by the Texas A&M University institutional review board (IRB2019-1128M).

Measures

Primary outcomes were caregivers' sense of belonging to their local community and perception of social supports available to them. Sense of belonging was examined using a single item ("my sense of belonging to my local community is…"), and participants rated their response on a slider ranging from 0 (none) to 100 (very strong). The survey adapted Lubben's Social Network Scale (23) to assess perceived social support available. Participants were asked how many relatives, friends, neighbors, other than the care recipient they see or hear at least once a month, feel close to, and feel they can call on for help (e.g., chores, transportation). Response options were: none, one, two-to-four, five-to-eight, nine or more, and uncertain. None responded 'uncertain' to any of the three items, and hence the response option was removed from the analysis. The Cronbach's alpha for the three items was 0.81.

The primary independent variable of interest was caregivers' use of communication technology (texting or communication applications). Participants were asked if they use texting or communication applications. WhatsApp, Facetime, Skype, and Google Hangouts were given as examples of communication applications. The use of communication technology was not restricted for caregiving purposes or any other purpose to capture the technology use in general.

The effect modifier was caregivers' paid status. Participants self-reported their caregiver type as paid (8.7%, $n = 44$), unpaid (82.9%, $n = 418$), and both paid and unpaid (8.3%, $n = 42$). For this analysis, caregivers who received payment for caregiving (i.e., "paid" and "both paid and unpaid") were considered as paid caregivers (17.1%, $n = 86$).

Sociodemographic variables examined included were age in years, sex, race/ethnicity, education, household income, perceived financial distress (24), and type of geographic area. Geographic area types were classified into metropolitan and non-metropolitan areas based on self-reported ZIP Codes and Rural-Urban Commuting Area (RUCA) Codes (25). Caregiver context was examined by asking their total weekly hours of caregiving to adults over age 50 living in a home environment and whether their family relationship was strained due to caregiving (yes/no).

Analyses

Means and standard deviations or frequencies and percentages were used to describe the study participants. Next, Chi-square tests or independent sample *t*-tests were used to compare sociodemographic characteristics, communication technology use, perceived social support, and sense of belonging to the local community between paid and unpaid caregivers. The descriptive statistics and comparison results are presented in **Table 1**. In addition, Chi-square tests and independent *t*-tests were used to compare sociodemographic characteristics of caregivers who did and did not report using communication technology. These analyses were performed separately for paid and unpaid caregivers. Multivariable regression analysis was performed to predict each outcome (i.e., sense of belonging and social support) based on the use of texting or communication applications. Multivariable regression analyses were repeated for each outcome variable after including the caregivers' paid status (paid/unpaid) and the interaction term between the caregivers' payment status and the use of communication technology. All regression models were adjusted for caregivers' age, sex, race/ethnicity, and education.

RESULTS

Study Participants

The average age of participants was 64.2 years (standard deviation = 8.53) and the majority was female (74.8%) and non-Hispanic White (66.9%). Compared to paid caregivers, unpaid caregivers were significantly older (64.5 vs. 62.2 years, $p = 0.022$) and a larger proportion were non-Hispanic White (70.8 vs. 47.7%, $p < 0.001$). Among the study participants, a higher percentage of paid caregivers had lower educational attainment (i.e., high school graduate or less education) than unpaid caregivers (30.0 vs. 18.8%, $p = 0.023$). The average weekly hours of caregiving for adults 50 years and older was 53.5 h (45.7 h among paid caregivers and 54.9 h among unpaid caregivers, $p = 0.123$). Paid caregivers reported a higher sense of belonging to their local community (65.1 vs. 55.1, $p = 0.005$), and both paid and unpaid caregivers reported some social support (i.e., approximately one to four relatives, friends, neighbors, other than their care recipient that they see or hear from at least once a month, feel close to, and feel they can call on for help) ($p = 0.838$).

Communication Technology Use

Nearly 83% of the study participants reported using texting or communication applications (81.5% among paid caregivers and 83.1% among unpaid caregivers, $p = 0.718$) (**Table 1**). For both paid and unpaid caregivers, there were no statistically significant differences in sociodemographic characteristics between those who used and did not use communication technologies.

Sense of Belonging

After adjusting for caregivers' age, sex, race/ethnicity, and education, a significantly higher sense of belonging was observed among paid caregivers than unpaid caregivers ($b = 9.40$, $p = 0.009$) (**Table 2**). There was no statistically significant difference in sense of belonging based on caregivers' use of texting or communication applications ($p = 0.218$). However, the interaction effect showed that among paid caregivers, the use of texting or communication application significantly increased their sense of belonging, but this relationship was less among unpaid caregivers (b_interaction = 21.28, $p = 0.022$).

Social Support

After adjusting for caregivers' age, sex, race/ethnicity, and education, the use of texting or other communication applications significantly increased caregivers' perceived

TABLE 1 | Study participants' sociodemographic characteristics, technology use, sense of belonging to their local community and social bonds, by caregiver payment status (paid/unpaid).

Characteristics	Mean (SD) or Frequency (%)			*Paid vs. unpaid: p-value*
	Overall (*N* = 504)	**Paid (*n* = 86)**	**Unpaid (*n* = 418)**	
Sociodemographic characteristics				
Age (years)	64.2 (8.53)	62.2 (9.34)	64.5 (8.32)	0.022
Female	376 (74.8%)	68 (79.1%)	308 (73.9%)	0.311
Non-Hispanic White	335 (66.9%)	41 (47.7%)	294 (70.8%)	<0.001
High school or lower educational attainment	101 (20.6%)	24 (30.0%)	77 (18.8%)	0.023
Household income < $50,000	247 (50.4%)	47 (58.8%)	200 (48.8%)	0.103
Financial stress				0.366
End up with some money left over	229 (47.6%)	32 (41.6%)	197 (48.8%)	
Have just enough money to make ends meet	180 (37.4%)	30 (39.0%)	150 (37.1%)	
Not have enough money to make ends meet	72 (15.0%)	15 (19.5%)	57 (14.1%)	
Non-metropolitan area	45 (9.1%)	7 (8.6%)	38 (9.2%)	0.868
Caregiving context				
Weekly hours of caregiving for adults over 50 years	53.5 (50.14)	45.7 (38.33)	54.9 (52.20)	0.123
Technology use				
Texting or communication applications	411 (82.9%)	66 (81.5%)	345 (83.1%)	0.718
Sense of belonging (score 0–100, higher score = stronger sense of belonging)	56.7 (29.16)	65.1 (30.94)	55.1 (28.6)	0.005
Social support availability (score 1–5, higher score = more social support)	2.7 (0.88)	2.7 (0.94)	2.7 (0.87)	0.838

TABLE 2 | Sense of belonging based on caregivers' payment status and use of communication technologies.

Predictors	Regression coefficient estimate	Regression coefficient standard error	*p*-value
Model 1[a]			
Using texting or communication applications (reference = not using)	4.41	3.57	0.218
Paid for caregiving (reference = not paid for caregiving)	9.40	3.60	0.009
Model 2[a]			
Using texting or communication applications (reference = not using)	0.73	3.90	0.853
Paid for caregiving (reference = not paid for caregiving)	−8.25	8.49	0.332
Interaction term (Using texting or communication application X Paid for caregiving)	21.28	9.28	0.022

[a]*Both models 1 and 2 were adjusted for caregivers' age, sex, race/ethnicity, and education.*

availability of social support ($b = 0.35$, $p = 001$) (**Table 3**). There was no statistically significant difference in perceived social support availability based on caregivers' payment status ($p = 0.816$). There was no statistically significant difference in the relationship between perceived social support availability and use of texting or communication applications, based on caregivers' payment status (b_interaction $= -0.36$, $p = 0.216$).

DISCUSSION

This study described communication technology use among middle-aged and older, paid and unpaid caregivers of adults 50 years and older in a natural (non-experimental) setting. It also examined the association between their communication technology use, perceived social support, and sense of belonging. In this cross-sectional online survey study, more than 80% caregivers used some form of communication technology (i.e., texting or other communication applications). This study included caregivers who were age 50 and older, and the observed rate of communication technology use is comparable with the rates reported in the 2020 American Association of Retired Persons (AARP) report on older adults' technology use (26). According to the report, about 91% of adults at 50 and older use technology to stay connected with friends and family. About 94% of adults ages 50 and older reported daily use of smartphones, and 83% of those who own a smartphone used instant messaging or email applications. It is important to note that both the current study and AARP report used online surveys, and therefore, the communication technology use rates may be overestimated. Despite the likelihood of over-estimation, this current study result supports high communication technology use rates among middle-aged and older caregivers and suggests

TABLE 3 | Social support availability based on caregivers' payment status and use of communication technologies.

Predictors	Regression coefficient estimate	Regression coefficient standard error	*p*-value
Model 1[a]			
Using texting or communication applications (reference = not using)	0.35	0.11	0.001
Paid for caregiving (reference = not paid for caregiving)	0.03	0.11	0.816
Model 2[a]			
Using texting or communication applications (reference = not using)	0.41	0.12	0.001
Paid for caregiving (reference = not paid for caregiving)	0.32	0.27	0.223
Interaction term (Using texting or communication application X Paid for caregiving)	−0.36	0.29	0.216

[a]*Both models 1 and 2 were adjusted for caregivers' age, sex, race/ethnicity, and education.*

that communication technology-based interventions may be useful to promote or maintain social relations and activities among middle-aged and older caregivers of middle-aged and older care recipients.

In the current study, paid caregivers reported a greater sense of belonging to their local community compared to unpaid caregivers. Communication technology use was positively associated with a sense of belonging to their local community among paid caregivers; however, this association was less pronounced among unpaid caregivers. According to Hagerty et al., antecedents of a sense of belonging are an individual's energy for involvement, likelihood, and willingness to be involved, and the likelihood of shared or complementary characteristics (12). In 2020, about 62% of informal caregivers of middle-aged and older adults were employed, and about 60% of them worked full-time (1). Unpaid caregivers, who might have another job, might have lower energy in the caregiving role and/or opportunity to be involved in the local community than paid caregivers. In terms of Hagerty's conceptualization of sense of belonging, paid caregivers may have more energy, and shared complementary characteristics with other paid caregivers in the similar field of occupation. Given the nature of paid caregiving, these caregivers may belong to other networks of employees or professional associations, where posing questions, posting feelings, and offering support on communication technologies may be more commonplace (or even expected). While the use of communication technology can potentially facilitate an individual's involvement in their local community, it may not be solely sufficient to promote involvement in the local community in those who lack the antecedents (i.e., energy, willingness, and shared or complementary characteristics).

In line with the study hypothesis, this study indicates a positive correlation between communication technology use and social support. This finding confirms prior work and strengthens the evidence that communication technology is a promising tool to enhance perceived social support among middle-aged and older caregivers (27, 28). In that there was no statistically significant difference in this relationship between paid and unpaid caregivers, communication technology-based interventions targeting social support can be effective for paid and unpaid caregivers.

This study has some limitations. First, this study used an online panel survey, and the study sample may not be representative of the middle-aged and older caregiver population in the US. Despite our efforts to resemble the middle-aged and older caregiver population, the nature of data collection (i.e., *via* online) excluded those without access to internet (22). According to the 2020 AARP report on family caregivers of adults 50 years and older, the majority of caregivers of adults 50 years and older were 50 years and older (56%) and non-Hispanic White (61%), and about 31% had high school graduate or less education (NAC and AARP). Using the data from the Integrated Public Use Microdata Series (IPUMS), the Paraprofessional healthcare Institute (PHI) reported that about 66% of the home care workers were younger than 55 years old; about 37% were non-Hispanic White; and about 53% had high school graduate or less education (29). While the reports do not specifically describe the sociodemographic characteristics of the caregivers 50 years and older, the observed sociodemographic comparison between paid and unpaid caregivers in this was comparable to the national reports. In this study, compared to paid caregivers, unpaid caregivers were older, were more likely to be a non-Hispanic White individual, and were less likely to have lower educational attainment (i.e., high school graduate or less education). To complement these findings, future efforts should utilize diverse sampling and data collection methods to advance what is known about communication technology use among paid and unpaid caregivers. Second, while the study sample included paid caregivers, the number was small (n = 86, 17%) and may not be representative of all paid caregivers based on their specialty or employer type. Furthermore, caregivers' paid status was loosely defined based on self-reported data (i.e., "what type of caregiver are you?" and "For this person, the oldest person for whom you provide caregiving, are you a paid caregiver?"). Third, this study examined only specific categories of communication technology (i.e., texting and other instant messaging and audio and video calls). While text message is the most frequently used technologies by middle-aged and older adults to stay connected with their social networks (92% in both 2019 and 2020), the online survey excluded the use of email and social media, which are also communication technology used to connect older adults to their networks (21, 26). Further, measurement of communication technology use did not distinguish between specific uses for professional or personal reasons among paid caregivers. Future studies should incorporate additional items

about the types and purposes of communication technology used among paid and unpaid caregivers. Fourth, the phrase "local community" was not defined for the survey respondents, which may have introduced subjectivity and bias in its interpretation across populations.

Despite these study limitations, the study provides new insights about the use of communication technology among paid and unpaid, middle-aged and older caregivers of adults 50 years and older. Sense of belonging (12, 30) and social support are important constructs related to health, and this study suggests positive relationships between these two constructs and communication technology use among these caregivers. Findings provide evidence supporting the potential of communication technology-based interventions to promote a sense of belonging and social support among middle-aged and older caregivers. Furthermore, this study also shows that communication technology may play different roles in connecting middle-aged and older caregivers to their local communities, which may also differ for paid and unpaid caregivers. Given the observed differences between these caregiver groups, a diverse set of interventions are likely needed to enhance sense of belonging and social support across paid and unpaid caregiver populations. For paid caregivers, such interventions may be dictated by the caregivers' training, issued technology, and industry standards. Interventions for paid caregivers may be more easily assessed in terms of the intervention reach, implementation, and effectiveness, relative to unpaid caregivers. Regardless of the paid or unpaid caregiver audience, interventions including communication technology should take into consideration aspects of the caregivers' social network and their access to, comfort with, and preference for communication technology. Because paid and unpaid caregivers are essential resources supporting an aging society, it is critical to understand their respective needs and the types of interventions that would be feasible and effective to improve their feelings of belonging and support.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of the language in the original informed consent. The data may be available on request from the co-author, MO, upon IRB approval. Requests to access the datasets should be directed to MO, mory@tamu.edu.

ETHICS STATEMENT

This study involves human participants and was reviewed and approved by Texas A&M University IRB. The participants provided their electronic informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SL led the data analyses and development of the initial manuscript draft. MO contributed to the data analyses and development of the initial manuscript draft. All authors contributed to the study conceptualization, data collection, and revision of the manuscript.

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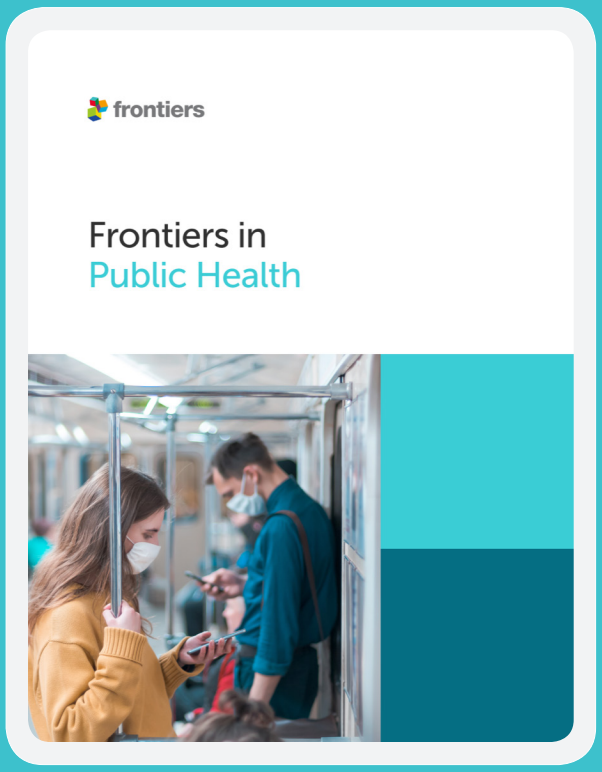

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