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Telemedicine in neurology, in dementia patient care and treatment

volume II

Edited by
Silvan Licher, Frank J. Wolters, Blossom Stephan, Thierry Moulin, Bart M. Demaerschalk, Thanh G. Phan, Amir Kheradmand, Susanne A. Schneider, Mario U. Manto and Aasef G. Shaikh

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Telemedicine in neurology, volume II: In dementia patient care and treatment

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SYSTEMATIC REVIEW
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A Systematic Review of Telemedicine for Older Adults With Dementia During COVID-19: An Alternative to In-person Health Services?

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Introduction: Older adults with dementia have been significantly at more risk for not receiving the care needed and for developing further mental health problems during COVID-19. Although the rise in telemedicine adoption in the healthcare system has made it possible for patients to connect with their healthcare providers virtually, little is known about its use and effects among older adults with dementia and their mental health.

Objective: This systematic review aimed to explore the use, accessibility, and feasibility of telemedicine in older adults with dementia, as well as examine the potential mental health impacts of these technologies, through reviewing evidence from studies conducted during COVID-19.

Methods: PubMed, Scopus, and Web of Science databases were searched with the following keywords: (COVID* OR SARS-CoV-2 OR Coronavirus) AND ("mental health" OR Depression OR Stress) AND (Dementia OR Multi-Infarct Dementia OR Vascular Dementia OR Frontotemporal Dementia) AND (elder OR Aging OR Aging OR Aged) AND (Telemedicine OR "Remote Consultation" OR telehealth OR technology).

Results: A total of 7 articles from Asia, Europe, and the United States were included in this review. Throughout the studies cognitive and mental health assessments (e.g., MoCA, FAST, etc.) were performed. Despite the barriers, telemedicine was noted as a feasible approach to assist individuals with dementia in connecting with their service providers and family while reducing complications related to travel (e.g., difficulty moving, traffic, distance).

Conclusions: Due to the COVID-19 pandemic, finding alternative ways to provide services to older adults with dementia through technology may continue to become more necessary as time goes on.

Keywords: telemedicine, older adults, dementia, mental health, COVID-19

INTRODUCTION

The COVID-19 pandemic rendered older adults more vulnerable to not receiving the healthcare needed and placed those living with dementia at an even increased risk for developing other mental health symptoms due to social isolation and loneliness (1). Telemedicine, an approach that incorporates information and communication technologies in the delivery of health care services for the diagnosis, treatment, prevention, and research and evaluation in order to advance patients' health outcomes, became more widely used following the dramatic rise in and the necessity for internet-based services during the COVID-19 pandemic (2). Telemedicine has proved a viable alternative in providing individuals with appropriate services and care along with mitigating against the effects of social isolation, especially in older patients with dementia [e.g., (3)].

Telemedicine is considered an effective option while reducing cost and increasing access to care in psychiatry treatment (4). According to a national poll released by the Canadian Medical Association (5), Canadians who connected with their doctor virtually during COVID-19 reported a high level of satisfaction (91%). Moreover, 46% of survey respondents who used virtual care would prefer a virtual method as a first point of contact with their doctor moving forward (5).

Although telemedicine is being more widely used as an effective and low-cost option, little is known about the impact of different telemedicine approaches on older adults with dementia and their mental health. Furthermore, the accessibility of telemedicine needs to be investigated as the use of beneficial technological alternatives to in-person health services may become more common post- COVID-19. This systematic review aims to explore the use, feasibility, and acceptability of telemedicine applications for older adults with dementia during the COVID-19 pandemic to address these gaps, as well as examine the potential mental health impacts of these technologies.

METHODS

Search Strategy and Keywords

This systematic review only included research articles from 2020 to October 2021. Relevant keywords and *Medical Subject Headings* (MeSH) were identified and searched through 3 databases: PubMed, Scopus, and Web of Science Core Collection. Quantitative, qualitative, and mixed-method articles were included. We applied the following filter within all databases: "English". In PubMed, we applied our search string within the query box marked with "All Fields". In Scopus, we applied our search string in the query box with "Article title, Abstract, Keywords". In Web of Science, we entered our search string in the query box with "All Fields" and we applied the following filter: "Open Access".

Search Criteria

PubMed, Scopus, and Web of Science databases were searched with the following keywords: (COVID* OR SARS-CoV-2 OR Coronavirus) AND ("mental health" OR Depression OR Stress) AND (Dementia OR Multi-Infarct Dementia OR Vascular Dementia OR Frontotemporal Dementia) AND (elder_ OR Aging OR Aging OR Aged) AND (Telemedicine OR "Remote Consultation" OR telehealth OR technology). The total number of number of articles across all 3 databases was 83 (PubMed: 28, Scopus: 26, and Web of Science Core Collection: 29). We also examined the references of articles to ensure we did not exclude any relevant articles (i.e., snowballing).

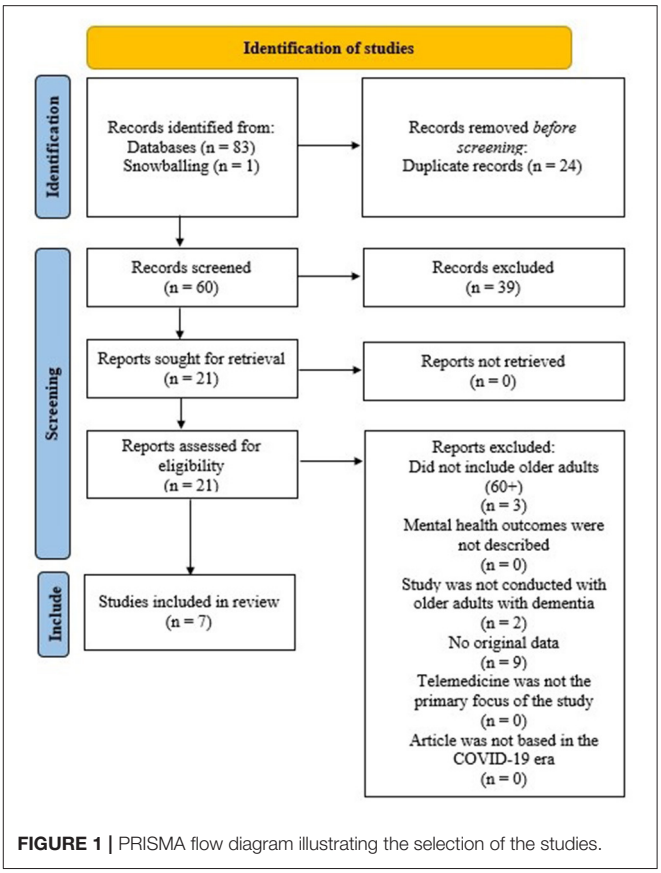

FIGURE 1 | PRISMA flow diagram illustrating the selection of the studies.

Selection of the Studies

Two independent reviewers (S.E.; K.C.) examined the articles and consulted with the senior researcher in the case of uncertainty (H.S.). From the combined total of the 3 databases, 83 articles were identified from the databases, of which 24 duplicates were removed and 1 article was identified via snowballing. Next, 39 articles were removed based on the titles not relating to the topic. We then assessed the abstracts of 21 articles, in which we applied the following exclusion criteria: (1) did not include older adults (60+) [3 article removed], (2) mental health outcomes were not clearly described [0 article removed], (3) the study was not conducted with individuals with dementia [2 articles removed], (4) no original data [9 articles removed], (5) telemedicine was not the primary focus of the study [0 article removed], (6) article was not based in the COVID-era [0 articles removed] (total n removed = 14). The resulting are the 7 published works included in this systematic review.

RESULTS

Overview of Studies Included

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram illustrating the selection process of the studies is presented in **Figure 1** (6). An overview of each of the seven articles included is provided in **Table 1**, including details on authorship, study design, the sample population, demographics, use of a control group, the aim of each study, assessments used, and important findings. Overall, the geographic locations of the studies included four studies conducted in Europe (7, 9, 10, 12), two in the United States of America (8, 11), and one in Asia (3). Most of the research articles focused on recruiting community-dwelling participants (3, 9–11), whereas the others recruited participants through convenience samples in clinics, hospitals, care homes, and day centers (7, 8, 12). All studies were conducted within the COVID-19 context.

Overall, only two of the seven articles included any form of control group or condition, which included participants receiving either a phone call or reduced telemedicine service (control) as compared to receiving the intervention in its full form [i.e., (3, 9)]. One of the studies, which used a control, utilized a cross-sectional survey design in which both the intervention and control groups had to respond to a telephone-based survey (9), whereas the other study had participants divided between a weekly phone call group and a weekly phone call plus video calling group (3).

Among the seven articles, five did not use control groups. Instead, the researchers performed longitudinal, cross-over, cross-sectional, or collaborative action research designs. Articles 2 (8), 5 (10), and 7 (12), from **Table 1**, investigated a number of medical clinics that were in the process of examining the feasibility and implementation of technological interventions for telemedicine services. Articles 1 (7) and 6 (11), as identified in **Table 1**, evaluated the roles of technology in older adults with memory decline and dementia and explored the potential barriers to technology use that individuals with cognitive decline or impairment may experience. Finally, the researchers attempted to test the benefits of emerging technologies in the third (3) and fourth (9) articles. Specifically, article 3 evaluated the beneficial impacts of phone calls or phone calls plus supplementary video calling (3) and article 4 evaluated a television-based technology (9).

Several different tests and assessments were used in the studies, which included measures of mental state or cognitive ability, experience, accessibility, etc. All studies included participants aged 65+. The majority of these studies, excluding Gately et al. (11), had both male and female participants. With regards to age, all studies, apart from Zamir et al. (12), conducted their work with adults aged at least 70 years and older, whereas the work by Zamir et al. (12) included participants aged 65 and over.

Various studies screened participants prior to the consultations. Several factors were screened for prior to participant enrolment in the respective studies, such as physical disabilities like strokes, terminal illnesses, visual impairment, motor impairment, auditory impairment, and negative affect (using the Geriatric Depression Scale [GDS]). Lai et al. (3) screened their participants to exclude individuals with a history of strokes. Goodman-Casanova et al. (9) conducted pre-screening for participants with motor, cognitive, and visual conditions that could affect the participants' use of the television-based technology. Zeghari et al. (10) also evaluated the feasibility and reliability of a mobile unit for cognitive testing and pre-screened individuals to ensure they were not presenting with significant visual or auditory limitations that could impact their participation.

Cognitive and Mental Health Outcomes

The studies used various cognitive tests, including the Mini-Mental State Examination (MMSE), Montreal Cognitive Assessment (MoCA), the Quality of Life in Alzheimer's Disease (QoL-AD) scale, Geriatric Depression Scale (GDS), etc., to assess the effectiveness of telemedicine. One study found significant differences in the MoCA scores of individuals with cognitive impairment receiving both telephone and video calls compared to the telephone service-only group (12). Comparatively, two other studies found no significant differences between their 2 groups, albeit with some discrepancies (9, 10).

Lai et al. (3) found that individuals receiving additional telemedicine video calls had significantly higher MoCA and quality of life (demonstrated through the QoL-AD) scores [MoCA: $F_{(1,58)} = 17.97$, $p < 0.001$, $\eta^2 = 0.24$; QoL-AD: $F_{(1,58)} = 5.54$, $p < 0.05$, $\eta^2 = 0.09$]. It was also remarked that within the 4-week period within which the study had begun, the control group's (receiving telephone calls only) MoCA scores fell by 1.83 points (3). Goodman-Casanova et al. (9), however, found no significant differences between their intervention group and control groups across all study variables, which included the GDS, MMSE, and an in-house developed survey. Comparatively, Arighi et al. (7) found no significant differences across MMSE scores from previous in-person visits to online teleconsultations. Moreover, Zeghari et al. (10) found no statistically significant differences between face-to-face and mobile testing, using two different versions of the MMSE, FAB, SVF, etc. This finding by Zeghari et al. (10) is noted as an important indicator for future implementation of mobile cognitive testing.

Practitioners', Participants', and Caregivers' Technological Feedback

Results on feedback specific to the use of technology were mixed. There were some concerns regarding the older participants' ability to access telemedicine consultations or services. For example, Arighi et al. (7) identified that 34 participants were unable to respond to their scheduled televisit due to poor connection issues. Additionally, having a young caregiver did have a significant impact on televisit success (7). This is perhaps due to the fact that the caregiver is able to support the participant with any troubleshooting. However, most of the studies [i.e., (8, 10–12)] did praise the implementation of technologically mediated solutions. Iyer et al. (8) explored the opinions of older adults with varying levels of cognitive impairment (based on

TABLE 1 | Summary of the studies ($n = 7$).

	References	Study design	Sample	Demographics	Population	Control	Aim/objectives	Other	Assessments	Conclusions
1)	Arighi et al. (7)	Cross sectional/ Longitudinal	108 (>70 years)	51.4% with successful televisit 41.2% male with failed televisit	Patients from the Alzheimer's Center of the Fondazione IRCCS (Italy)	No control	To examine the issues with access to/use of digital technology (i.e. digital divide) in older adults with dementia contacted through videoconferencing		Remote neurologist consults/ interviews, MMSE	68.5% (74 patients) successfully connected via televisit 31.5% (34 patients) failed to respond to the televisit Failure to respond to televisiting due to connection difficulties do not access to devices/Internet Presence of young caregiver significantly influences televisit success (p <0.001, OR 5.14).
2)	Iyer et al. (8)	Longitudinal	43 (M_{age} = 85.5 years)	72.1% had degree of cognitive impairment	Older adults that receive services from an academic outpatient geriatrics clinic (USA)	No control	To examine the feasibility and acceptability of telemedicine visits in clinic serving older adults with a high proportion of cognitive impairment		Face-to-face or phone calls interviews 7-question optional experience survey for patients or caregivers 4-question survey for clinical providers	Patients and clinicians responses did not differ in *similarity of in-person visit* (p =0.999). Patients indicated greater comfort with using video or telephone visits in the future Telemedicine services are appreciated for frail, older adults
3)	Lai et al. (3)	Longitudinal	60 [30 control and 30 intervention] M_{age} patients with NCD = 72.73 ± 0.84 years) (M_{age} Caregivers = 71.83 ± 0.80 years	21 patients in the control group received between 4- 8 hours of support by family, 9 received > 8 hours of support 15 patients in the intervention group received between 4- 8 hours of support by family, 15 received > 8 hours of support	Convenience sample of community-dwelling people with cognitive impairment and spousal caregivers through an activity day center for older adults (China)	Control	To evaluate the extent to which both telehealth videoconferencing and regular telephone calls would provide benefits to older adults with NCD and their caregivers during COVID-19	Older adults with NCD presenting with major physical disabilities, such as strokes were excluded	Weekly telephone calls/ Weekly health services via Zoom, WhatsApp, or Facetime. Validated Chinese versions of MoCA, RMBPC, QoL-AD SF-36v2; ZBI scale, RCSES	Additional telemedicine had a significant impact halting the reduction of MoCA scores that was shown in the telephone-only group ($\eta 2 = 0.50$). Improvements in physical and mental health of caregivers in the video-conferencing group but not telephone-only ($\eta^2 = 0.23$–0.51).

(Continued)

TABLE 1 | Continued

	References	Study design	Sample	Demographics	Population	Control	Aim/objectives	Other	Assessments	Conclusions
4)	Goodman-Casanova et al. (9)	Cross-sectional Survey Part of a larger RCT	93 (M_{age} = 73.34 years)	65% of the sample were women 74% were living with other people	Community dwelling older adults with mild cognitive impairment/mild dementia recruited through convenience sample by the Biomedical Research institute of Malaga (Spain)	Control	To explore the impact of confinement on the health and well-being of community-dwelling older adults with mild cognitive impairment or mild dementia To provide television-based and telephone-based health and social support To evaluate a television-based technology for older adults with various forms of cognitive decline	Older adults with a score of > 11 on the GDS, terminal illness, and Individuals with cognitive, visual, motor conditions that could affect the system were excluded.	GDS MMSE Telephone based survey with open ended (qualitative) and numerically based (quantitative) questions administered by health professionals	No significant differences between intervention and control groups across all study variables ($p > 0.05$) Participants with TV-AssistDem did perform more memory exercises than the control group ($p < 0.001$).
5)	Zeghari et al. (10)	Observational cross-over	8 (M_{age} = 76.7 years)	4 men; 4 women	Community dwelling participants that are socially isolated (France)	No control	To evaluate the feasibility and reliability of mobile unit settings for remote cognitive testing	Individuals with significant vision and auditory problems which would impact ability to perceive and understand the clinician were excluded	Short clinical interview, cognitive screening tests, Acceptability scale, Two versions of MMSE, FAB, 5 words: 5 mots de Dubois; SVF; PVF; DS	No significant differences between in-person testing vs mobile testing (ps = 0.115–1) Acceptability scores revealed that all participants found the MU easy to access and as comfortable ass being face-to-face
6)	Gately et al. (11)	Cross-Sectional	24 ($range_{age}$ = 45 - ≥ 75)	Veterans with dementia (100% Male) All participants were white. One caregiver had prior experience with teleconferencing services for dementia management, all caregivers had experience with video conferencing	Community-dwelling caregivers of Veterans with Dementia (USA)	No control	To evaluate the role of in-home video telehealth technologies to meet the needs of caregivers and persons with dementia To identify strategies to adapt in-home video telehealth services		Semi-structured qualitative interviews (approx. 20 minutes long)	Caregivers describe that telehealth services can be beneficial as a follow-up service Caregivers propose that one barrier technological implementation for older adults with dementia is that they may have limited ability to engage/manage the devices without help
7)	Zamir et al. (12)	Collaborative action research (CAR)	22 older adult residents (≥ 65 years) 8 facilitators (22–50 years)	7 residents with dementia or signs of cognitive decline 12 residents with hearing impairment 9 with visual impairment 3 that are non-verbal 6 that are frail	Convenience sample of older adults in care homes (UK)	No control	To explore the feasibility and accessibility of whether video-calls between care homes could reduce loneliness and social isolation in older adults.		Ethnographic approach consisting of observations, informal unstructured feedback, memo writing and semi-structured interviews	Five dominant themes were revealed Some residents living in the care home seemed to have regained their energy and self-purpose because of the video calls. Therefore, the increase of the residents' social networks by connecting them to other care home residents may have helped decrease their loneliness

Functional Assessment Staging Tool [FAST] scores) through qualitative interviews and found that although clinicians found video technology services burdensome, patients and caregivers did not. In fact, patients reported feelings of connectedness and appreciated the discussions (8). Despite their initial disdain for arduous technological implementations, the service providers were appreciative of the ability to have many family members that were across geographically different areas united to discuss the patient's health (8).

Gately et al. (11) identified that caregivers valued video telemedicine services for their ability to greatly reduce travel needs (both issues with distance and travel but also facilitating dementia-related decreases in mobility and cognition), and increase the ability of family members with physical limitations or living far away to engage in medical visits. Zeghari et al. (10) contend that remote neuropsychological testing through their mobile unit and video chat system was a feasible endeavor. This was supported by scores on an accessibility scale in which participants considered the virtual call comparable to face-to-face meetings (10). Zamir et al. (12) revealed that telemedicine calls between care homes provided some residents with renewed energy and self-purpose.

Barriers to Technological Adoption

Of the seven studies included in this review, four considered the potential barriers to technological adoption for older adults living with memory decline, Alzheimer's, and dementia (i.e., (7, 8, 11, 12). Gately et al. (11) noted several barriers, including the challenges of having discussions with older adults with cognitive issues over video (due to technical issues or natural decreases in focus/attention), potential difficulties for service providers in acquiring an accurate representation of the care recipient, etc. Arighi et al. (7) proposed that lack of access to a helpful caregiver may hinder the patient's ability to properly use the technology. Similarly, Iyer et al. (8) cite difficulties such as lack of technological literacy and devices with cameras. Zamir et al. (12) identified five themes (i.e., regaining sense of self and purpose, residents with dementia remember faces not technology, inter and intra connectedness, organizational issues creating barriers to long-term implementation, and situational loneliness to overcome) all of which may create long-term barriers to implementation.

DISCUSSION

This systematic review aimed to explore the use, feasibility, and acceptability of telemedicine applications for older adults with dementia during the COVID-19 pandemic. In this systematic review, we explored seven articles implementing various forms of telemedicine projects ranging from video and telephone calling [e.g., (3, 7, 10–12)], and modification of everyday technologies such as televisions [e.g., (9)]. The findings of this systematic review clarify noteworthy developments within telemedicine research in the wake of COVID-19 delivered to older adults with dementia [e.g., refinement of remote cognitive assessments through a mobile unit (10), or developing television-based treatments that are intuitively designed for older adults with dementia (9), etc.]. Two main themes were observed: *the barriers remaining to telemedicine implementation, in the wake of COVID-19* and *the benefits of telemedicine use during COVID-19*.

Notably, COVID-19 not only led to improvements in Internet-based services but was a strong catalyst that led to the dramatic, widespread adoption of telemedicine in healthcare systems worldwide, and somehow, this approach to care fit in the notoriously conservative healthcare industry, which is typically slow to adopt novel technologies (13–16). Indeed, the elderly have become one of the predominant demographics targeted for telemedicine projects as these devices have the possibility to connect, monitor, and assist seniors with healthcare professionals, emergency services, and family members across large distances without the need for in-person, face to face, interactions (17).

As the number of telemedicine projects continues to rise in response to the pandemic, it should be noted that the group for which the technology is perhaps most imperative (i.e., older adults with cognitive decline – most at-risk for COVID-19) may not be fully equipped to use it without the proper assistance (7, 11, 14). To begin with, the lack of knowledge and digital literacy are established causes of stress and disengagement with technology among older adults (18, 19). More so, older adults are typically less accustomed to technologies and may avoid them entirely (10). In this situation, a competent caregiver would play a crucial role (11). This distinction is further exemplified by Gately et al. (11), who affirm that without proper help and support, even individuals living with a mild form of dementia may have significant difficulties with using telemedicine services which would worsen as the disease progresses.

Arighi et al. (7) further noted the importance of caregiver assistance as a moderator for the success of their telemedicine intervention. Notably, it was found that when older patients received the support of younger caregivers (e.g., children or grandchildren), telemedicine consultations were significantly more successful (7). Zamir et al. (12) also posited that telemedicine approaches should be facilitated by younger care staff. The current systematic review revealed several barriers remaining within telemedicine practices applied to the geriatric population, specifically, individuals living with dementia, such as the inability to deal with technical issues, connectivity problems, as well as the loss of information due to being unable to properly examine the patient (7, 8, 11, 12).

Nevertheless, a consensus remains that telemedicine could positively impact patients and their access to healthcare [e.g., (8, 10–12)]. This suggests that despite the current issues that older adults with dementia may face, there remains an overall positive aspect to providing services via technology. Lai et al. (3) further propose the impact of their telemedicine intervention (via video conference) to help their older participants develop a stronger resilience to the effects of COVID-19 related isolation (as shown through improvements in the intervention groups QoL-AD scores).

Moreover, in all seven studies, the older adults showed a trend toward admiration for these technologies (3, 7–12). For example, chatting with physicians via video calls was welcomed [e.g., (3, 8–10)] and having access to telemedicine-based television services

resulted in increased use of memory exercise game use (9). It may also indicate that older adults are willing to engage with new technologies if they recognize the benefits of using the device and have access to the technology. This is corroborated by Heinz et al.' (20) work, whereby it was proposed that seniors' motivation to engage with technology is higher when they are able to perceive the added benefits of technology use, such as increased autonomy and a better quality of life. Overall, these findings suggest that while there may be a concern regarding older adults' ability to use telemedical services, the benefits of digital interventions could outweigh this concern. This would be possible with proper design, support, oversight from caregivers and staff, in addition to providing a greater understanding of the usefulness of these tools to older adults.

Some limitations exist within the current set of studies. For instance, few quantitative mental health assessments were included. One such example is the study by Zamir et al. (12), in which they conclude that older adults' mental states were improved, as demonstrated through their qualitative analyses. Due to the limitations of qualitative research (e.g., lack of quantification of change), adopting the use of a mixed-method design in follow-up work can broaden the exploration and integration of these findings to provide a more complete interpretation of what the participants are experiencing (21, 22). Additionally, the majority of the telemedicine assessment or interventions that were identified were video conference-based. Finally, the current systematic review did not examine telemedicine practices occurring pre-pandemic. Future studies could perhaps examine the evolution and changes that telemedicine has undergone since the arrival of COVID-19 and examine individuals' experiences longitudinally.

CONCLUSIONS

Based on the existing body of literature during COVID-19, telemedicine assessment and intervention approaches focusing on supporting older adults with dementia are presented as helpful tools. Despite the notable barriers that exist, such as those involving accessibility and digital literacy, it should be considered that telemedicine approaches and intervention remain a feasible alternative to connecting with individuals while reducing complications related to travel (e.g., difficulty moving, traffic, distance). Given the COVID-19 pandemic's international impact and the physical distancing and isolation measures it imposes, finding alternative ways to connect may continue to become more and more essential.

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

HS and SE conceived the presented idea and framework for the systematic review. SE conducted the search for articles in consultation with HS and made the table and completed the PRISMA diagram. SE and KC analyzed the articles in consultation with HS and drafted the manuscript. SE, KC, and HS were involved in the planning of the manuscript. KS, JG, CR, KB, KN, PL, KG, IV, and SR revised and provided feedback for the manuscript. All authors revised and approved the final manuscript.

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Design and Development of a Mobile Health (mHealth) Platform for Dementia Prevention in the Prevention of Dementia by Mobile Phone Applications (PRODEMOS) Project

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Background: Mobile health (mHealth) has the potential to bring preventive healthcare within reach of populations with limited access to preventive services, by delivering personalized support at low cost. Although numerous mHealth interventions are available, very few have been developed following an evidence-based rationale or have been tested for efficacy. This article describes the systematic development of a coach-supported mHealth application to improve healthy lifestyles for the prevention of dementia and cardiovascular disease in the United Kingdom (UK) and China.

Methods: Development of the Prevention of Dementia by Mobile Phone applications (PRODEMOS) platform built upon the experiences with the Healthy Aging Through Internet Counseling in the Elderly (HATICE) eHealth platform. In the *conceptualization* phase, experiences from the HATICE trial and needs and wishes of the PRODEMOS target population were assessed through semi-structured interviews and focus group sessions. *Initial technical development* of the platform was based on these findings and took place in consecutive sprint sessions. Finally, during the *evaluation and adaptation*

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phase, functionality and usability of the platform were evaluated during pilot studies in UK and China.

Results: The PRODEMOS mHealth platform facilitates self-management of a healthy lifestyle by goal setting, progress monitoring, and educational materials on healthy lifestyles. Participants receive remote coaching through a chat functionality. Based on lessons learned from the HATICE study and end-users, we made the intervention easy-to-use and included features to personalize the intervention. Following the pilot studies, in which in total 77 people used the mobile application for 6 weeks, the application was made more intuitive, and we improved its functionalities.

Conclusion: Early involvement of end-users in the development process and during evaluation phases improved acceptability of the mHealth intervention. The actual use and usability of the PRODEMOS intervention will be assessed during the ongoing PRODEMOS randomized controlled trial, taking a dual focus on effectiveness and implementation outcomes.

Keywords: mHealth, dementia, cardiovascular disease(s), prevention, design concept, behavioral health

INTRODUCTION

The projected worldwide increase in dementia prevalence is expected to largely occur in low- and middle-income countries and amongst hard-to-reach populations in high-income countries (1, 2). An estimated 30–40% of late-life dementia appears to be attributable to potentially modifiable risk factors, including smoking, insufficient physical activity, and unhealthy diet (3). Interventions targeting these risk factors may have the potential to delay or prevent dementia onset and could be especially beneficial for vulnerable populations, given their high exposure to high risk of these behaviors (4, 5).

The rapid increase of internet access through mobile devices may have the potential to bring preventive healthcare within reach of large groups of people who have limited access to preventive services (6). Mobile health (mHealth) applications can contribute to personalized care and remote delivery of health messaging and services, at low cost and on a global scale (7, 8). Seizing the business opportunity healthcare applications have mushroomed, rising to over 90 000 in app stores in the first quarter of 2020 (9, 10). However, very few of these have been developed following an evidence-based rationale, or have been tested for efficacy in a (randomized controlled) trial. While the conceptualization and architecture of such mHealth interventions are key aspects of development with respect to its perceived usability, uptake, and ultimately success, guidelines to design mHealth interventions for vulnerable populations are not readily available (11).

In the Prevention of Dementia using Mobile Phone Applications (PRODEMOS) trial, we will assess the effectiveness and implementation of a coach-supported mHealth platform to reduce dementia risk over a period of 18 months. The study population will consist of 1,200 older adults with low socioeconomic status (SES) from the United Kingdom (UK) and 1,200 older adults from Beijing, China, all with 2 or more lifestyle factors at levels associated to an increased dementia risk (12). In this article, we describe the development of the PRODEMOS mHealth intervention, from general idea to platform design, and from prototype to pilot study. We make specific recommendations on mHealth design for vulnerable populations, based on extensive interactions with the target population and other important stakeholders, including health care professionals, software developers, and researchers.

METHODS

Context of PRODEMOS Study

The platform described in this paper was designed as part of the PRODEMOS trial. Development of the PRODEMOS platform built on the Healthy Aging Through Internet Counseling in the Elderly (HATICE) eHealth platform, which was designed and piloted between 2013 and 2016 and proven effective for lowering cardiovascular risk amongst European older adults in a randomized controlled trial (RCT) (13, 14). The coach-supported HATICE platform enabled self-management of cardiovascular risk factors, integrating European guideline recommendations on prevention of cardiovascular disease (CVD) and principles of Bandura's social-cognitive theory of self-management and behavioral change (15).

In PRODEMOS, we will focus on dementia prevention, however, with up to 50% of modifiable risk factors for dementia being cardiovascular risk factors we were still able to incorporate experiences and evidence from the HATICE trial (3, 16, 17). Given the rising smartphone penetration rates worldwide (18), and because especially in LMIC people tend to access and use the internet through smartphones rather than personal computers (19), we decided to develop the PRODEMOS platform as an mHealth intervention. The PRODEMOS platform is built to facilitate the self-management of risk factors for dementia, including overweight, hypertension, high cholesterol, diabetes, unhealthy diet, smoking, and insufficient physical activity. In line with the HATICE platform, PRODEMOS participants are able to

set SMART (Specific, Measurable, Achievable, Realistic, Timely) lifestyle goals, enter measurements, read goal-related education materials, and receive personalized lifestyle- and goal setting support via chat messaging from a remote coach.

The mobile application will be connected to a coach portal, allowing for remote lifestyle support by a health coach. The PRODEMOS platform also comprises a separate assessor- and researcher portal for data collection and outcome assessment, and a static mobile application with written healthcare advice only and without interactive features, for those randomized to the control condition of the trial. The assessor- and researcher portals and control application have been designed within the research context of the PRODEMOS project, of which the protocol is described in more detail elsewhere (12). **Figure 1** shows the components of the PRODEMOS platform and their interrelationships. All key functionalities of the PRODEMOS platform will be similar in the UK and China. Besides differences in language, certain cultural adaptations will be made to ensure adequate fit of the intervention with the target population. The PRODEMOS mobile application will be built to support participants with limited digital literacy, operationalized as at least being able to send a message using a smartphone.

Phases of Development

The development of the PRODEMOS platform is visualized in **Figure 2**. Although technical interventions are typically developed in an iterative cycle of overlapping phases, several distinct phases can be distinguished in the development of the PRODEMOS platform.

Conceptualization

First, we performed a thorough evaluation of the HATICE platform, focusing on the perceived value and usability of the eHealth intervention, as well as on the overall implementation. Through thematic analysis of semi-structured interviews with HATICE participants, we learned which factors affected initial and sustained engagement with the eHealth platform (20). In subsequent focus groups, we asked HATICE participants and coaches to share their experiences, views and recommendations for future use of the platform and coach support.

Following this, we assessed the specific needs and wishes of the PRODEMOS target population regarding an mHealth intervention to change their lifestyle behavior. We performed semi-structured interviews with 19 low SES Dutch older adults and 26 Chinese older adults and thematically analyzed them (21). To gather further data on the needs of the target population for successful use of the platform and remote coaching, focus group sessions with older adults of low SES were held in both the UK and the Netherlands. In separate sessions, other stakeholders, including Clinical Research Network nurses and experienced health coaches, were interviewed about their perspectives regarding coach-support for vulnerable populations.

Initial Technical Development

Based on the HATICE eHealth platform and the additional lessons learned, the study group drafted an outline capturing all necessary functionalities for the new portal and mobile application. Initial technical development was undertaken by Philips Vital Health (PVH; for the UK) and Fuzhou Comvee Network & Technology (Comvee; for China) in 2-weekly "sprint" sessions over 4–6 months, according to the agile principle (22). In iterative cycles, researchers from the coordinating research team at Amsterdam UMC provided detailed descriptions of all desired functionalities and gave feedback on functionalities that were newly developed.

Evaluation and Adaptation

Following initial technical development, the functionality of the portal and mobile application were meticulously evaluated. Software experts from PVH and Comvee and researchers from the coordinating research team, UK, and China internally tested the software. During "thinking aloud" sessions, we asked potential participants to navigate through the mobile application and directly share their thoughts with the developers. The developers also tested user experience (i.e., how the participants interact with the mobile application) and the user interface (i.e., the look and feel, presentation, and interactivity of the mobile application) with potential participants using predefined scripts and success criteria for participants to navigate through the most important functionalities of the application. The functionality of the portal and mobile application was subsequently trialed in six-week pilot studies in the UK and China. We used qualitative data, gathered through focus groups with pilot participants and participating coaches, and data on user statistics to evaluate usability. User statistics included details on goals, measurements, and chat history and were gathered manually from the platform, as the automated export functionality for user statistics had not been finalized by that stage. Findings from the internal test sessions, thinking aloud session, and pilot evaluation informed the final adaptation phase, in which the portal and mobile application was prepared for use in the full trial.

Unless stated otherwise, all qualitative sessions were led by at least one member of the research team and one member of the technical team, following a topic guide. We audiotaped all sessions and shared written summaries with the coordinating research team. Through plenary discussions between the researchers and technical developers, we translated the evaluation results into concrete development steps when deemed appropriate and feasible. More detail on demographics, methodology and recruitment of the evaluation processes is provided in **Supplementary Table 1**.

RESULTS

Conceptualization Phase

Lessons Learned From the HATICE Study

Prior to the start of the development of the PRODEMOS mHealth portal and mobile application construction, a qualitative evaluation among participants and coaches of the HATICE intervention took place. This demonstrated that most participants had appreciated the HATICE platform and coach support, and felt that it had helped them to pursue their lifestyle goals. Participants had used the platform mostly in a reactive way, by responding to notifications about chat messages

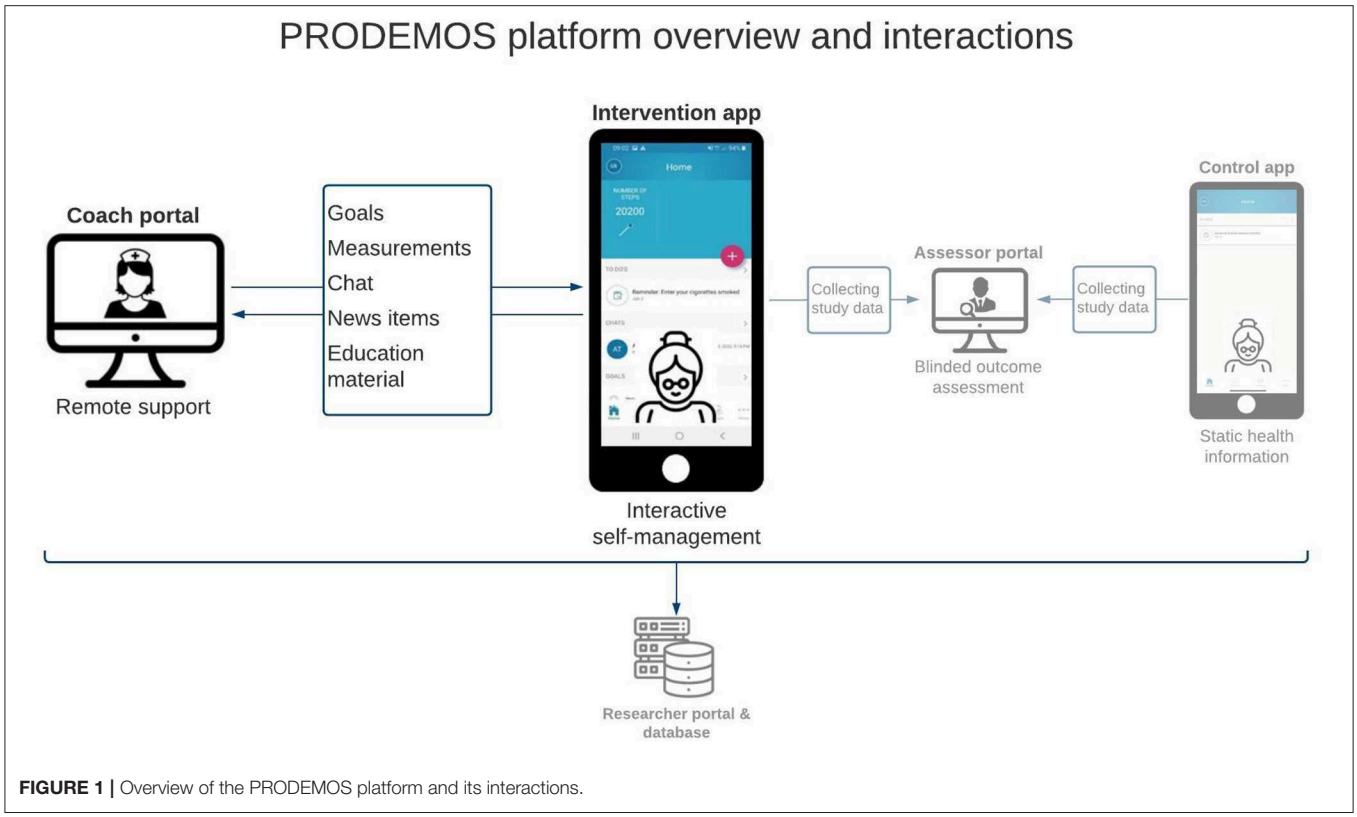

FIGURE 1 | Overview of the PRODEMOS platform and its interactions.

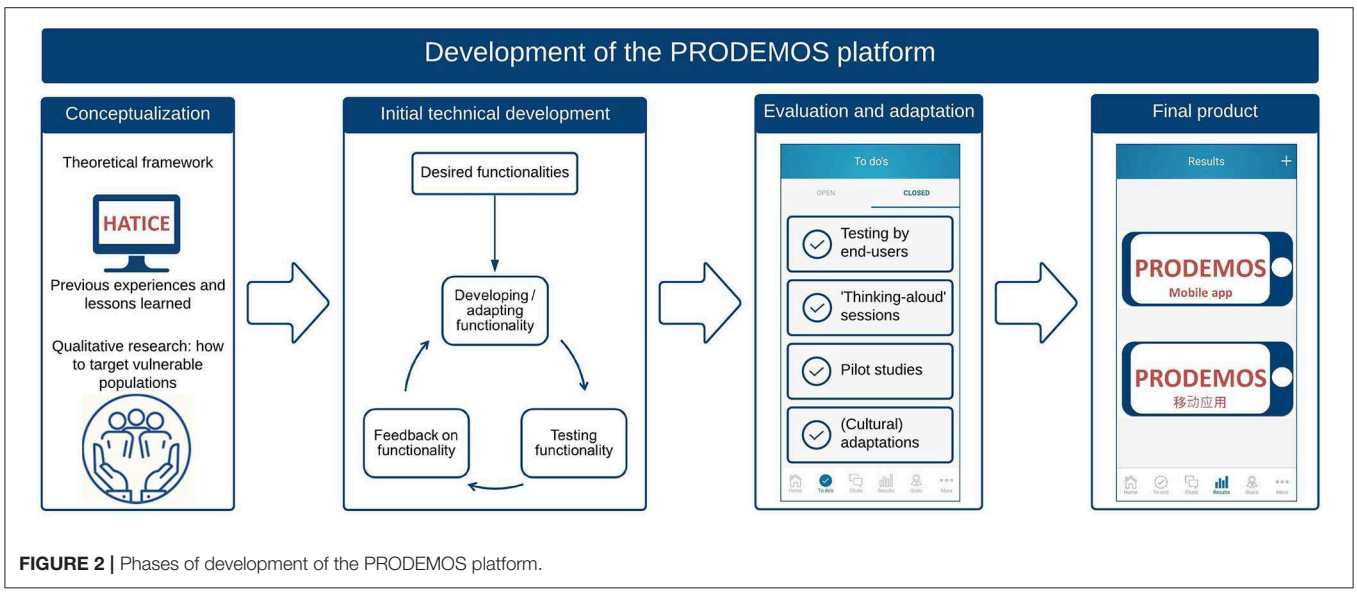

FIGURE 2 | Phases of development of the PRODEMOS platform.

and questionnaires (20). To capitalize on this finding, more (automatic) reminders to enter measurements were built in to the PRODEMOS mobile application, the frequency and content of which can be adjusted to the participant's needs. The qualitative evaluation of HATICE also revealed that participants had a wish for more tailored and frequently updated education material to stimulate sustained engagement over time. Furthermore, they expressed a need for more options to tailor the intervention to (changes in) their personal situation. As a response, we developed several additional features to facilitate personalization of the intervention, as displayed in **Supplementary Table 2**. Some HATICE participants noted that they had rarely used several functionalities of the intervention and thought that additional guidance, e.g., by adding a tutorial video on the home page, could help participants to make more use of all features of the platform. We therefore built an

explanatory animation video accessible through the library of the mobile application, covering the main functionalities of the PRODEMOS application.

From the HATICE trial, we learned that coach support was very important to stimulate both initial and sustained platform use. Participants expressed a need for active encouragement from the coach when a goal was reached or when their commitment weakened. Similarly, as HATICE coaches would have liked to keep better track of their participants' progress, we redesigned certain functionalities of the coach portal to facilitate better support of participants, as shown in **Supplementary Table 2**.

Lessons Learned From Potential PRODEMOS End-Users

Input from focus group sessions and individual interviews with older adults at increased cardiovascular risk in China and of additional low SES in the Netherlands and the UK, and focus groups with healthcare professionals in the UK and China was used to tailor the intervention to the PRODEMOS end-users. For the current section, we distinguish aspects of user-friendliness and personalization of the PRODEMOS mobile application.

User-Friendliness

As previously mentioned by the HATICE participants, members of the target population expressed the desire for a simple and intuitive-to-use mobile application, for example as suggested by a 77 year old male interview participant: *"If you're going to introduce this [app], you'd really have to educate a group of people, like how do you use something like that?."* Both potential coaches and participants favored pre-set options for lifestyle goals, to ensure easy-to-achieve and feasible goals. We developed the goal-setting flow in such a way that participants are able to build their lifestyle goals in several consecutive steps with wide choice from pre-set options, using the SMART principle (e.g., losing weight by increasing physical activity levels by walking twice a week for 30 mins). Participants also indicated the need for positive framing (e.g., 'improving blood pressure' as opposed to 'working on high blood pressure') and easy (non-medical) language, for example a 63 year old female interview participant: *"[The app has to be] understandable! Don't go tossing around big words and medical terms and all that."* For this, we have adapted the wording throughout the mobile application. Another important aspect of a user-friendly intervention was trustworthy and easy-to-understand material. Lastly, we have simplified log-in procedures, to facilitate easy access (**Supplementary Table 2**). Based on wishes from the Chinese target population, we made the Chinese mobile application available as a WeChat sub-application or "mini-program." WeChat is a widely used Chinese multi-purpose messaging, social media, and mobile payment application with a wide range of such mini-programs.

Personalization

In addition to user-friendliness, personalization of and flexibility during the intervention were regarded important aspects of (digital) lifestyle support. We learned from interviews with members of the target population that their lifestyle goals are often very specific, person-related, and result-driven on the short term (e.g., losing weight to fit in their favorite jeans rather than to prevent future chronic disease; 63 year old male interview participant *"[…]I can hardly tie my shoelaces. And look, that annoys the hell out of me. But now I've been wearing slippers for 3 months […]so now I'm not annoyed. And soon I'm gonna have to wear my shoes again, and maybe that will cause to flip a switch."*). Also, members from the target group mentioned that lifestyle advice should be tailored to their personal situation. As we learned that Chinese elderly often perform *tai chi* or square dancing (i.e., low-key dancing groups on public squares) in order to stay active, we included corresponding options to the Chinese mobile application. A comprehensive overview of adaptations made to the mobile application based on input from the PRODEMOS target population can be found in **Supplementary Table 2**.

Technical Development

Following the lessons learned, technical development of the UK platform commenced in April 2019. In accordance with the project planning, development in China started in July 2020. Due to differences in hosting requirements between the countries, both platforms were developed and hosted in separate environments in the UK and China. As mentioned previously, both platforms were developed based on the same concepts and requirements, with certain cultural adaptations wherever deemed necessary.

The development of the platforms followed an iterative process, allowing for timely redirection and adaptations. Development was evaluated every other week with the European and Chinese software developers. To bridge the gap between (medical) researchers and technical developers, we used storyboards, containing user-stories, and functional flow block diagrams, mapping all connections between the coach portal and the mobile application. The platform and mobile application were ready for preliminary internal testing by the developers and coordinating research team 5 months after the initial start of development. An overview of the basic functionalities of the PRODEMOS application can be found in **Supplementary Figure 1**.

Evaluation and Adaptation Phase

Internal Testing

After internal testing by the technical developers, the software was meticulously tested by the coordinating research team to detect potential technical issues, e.g., software bugs. One or more software developers were present during these test sessions to immediately investigate encountered issues and to deliver technical support where needed. After several test cycles, researchers and health coaches from the British and Chinese teams gained access to the mobile application and coach portal to interactively test the system over a longer period of time. The majority of findings concerned software bugs that had to do with the interaction between the mobile application and coach portal. Findings were recorded in a living document. After prioritization on relevance, urgency, and feasibility in collaborative sessions, findings were resolved by the software developers.

User Test and Pilot

After internal testing, the platforms were evaluated through thinking aloud sessions and pilot studies. The thinking aloud session provided good insight into the (intuitive) handling of the mobile application by our target population. Findings yielded mostly suggestions to further improve its usability and user-friendliness. Subsequently, the mobile application and portal were tested in a six-week pilot study in both the UK ($n = 21$) and China ($n = 56$). This way, we gained information about frequently used and potentially neglected functionalities and options in the app (e.g., goals were often set by sending chat messages to the coach rather than by using the goal-setting engine; the library was often overlooked).

In the UK, participants indicated the need for more intuitive operationalization of the mobile application with a consistent user interface. Text density and font size needed to be adjusted to better suit the target population. Moreover, log-in procedures were often found to be too complex. In China, as there is already a lot of information available on *WeChat*, participants stressed the need for more in-depth education material.

Coaches in the UK expressed the need to further improve the graphical overview of the progress of participants. Moreover, coaches felt like they would be able to support participants better if they were able to help participants with their goal setting by adjusting certain aspects, such as the evaluation date or the goal target, to make the goals more achievable or relevant. Additionally, coaches in China indicated the need for more extensive instructional information explaining the mobile application and coach portal. A more detailed description of adaptations made to the mobile application and platform based on the evaluation findings is displayed in **Supplementary Table 2**.

DISCUSSION

In this paper, we describe the design, development, and piloting of an mHealth portal and mobile application for the prevention of dementia in the context of the PRODEMOS trial, building upon the existing evidence and experience from the HATICE eHealth platform. Based on extensive input from all stakeholders involved, we developed a platform for behavior change for older adults, with adaptations for specific needs from the low SES population in the UK and the general population in China.

For the thorough development of an mHealth platform, many stakeholders from several backgrounds need to be involved, including researchers, healthcare professionals, software developers, and the target population. We believe clear communication is crucial to understand each other's idioms and ways of thinking during development and evaluation. We identified several learning points for open and clear communication between the involved parties. Structural (weekly) meetings stimulated transmission of knowledge and updates on progression. We believe this kept the whole team informed on advancement and allowed timely redirection if necessary. During these meetings, we kept structural documentation on wishes, adaptations and platform errors.

Involving potential end-users in the development process is thought to result in a more appropriate platform design (23–26). To optimally benefit from the feedback of (potential) end-users, we think the timing of these evaluation sessions is of great importance. Early involvement of end-users may be ideal, giving the developers sufficient time to optimally translate feedback into platform development. However, we learned that obtaining specific feedback on platform functionalities in the early stages can be very challenging for potential end-users, given its theoretical and conceptual rather than practical setting. Demonstrating a prototype of the platform, by using clickable designs and wireframes, can make these concepts more tangible, probably increasing the yield of end-user involvement in platform development. User testing of the preliminary functionalities through thinking aloud sessions greatly improved our insights in potential pitfalls of the platform and allowed for early adaptations. Our experience was that the direct presence of software developers during these sessions can benefit the user-centered design process, resulting in more mutual understanding and, ultimately, greater efficiency and quality.

Limitations

While the evidence-based development of the PRODEMOS portal and mobile application provides exciting opportunities to test the efficacy and implementation of an mHealth intervention in vulnerable populations, we faced several limitations. During focus groups, potential end-users expressed a wish for peer contact and activities to initiate and sustain behavior change. We have investigated the possibilities of incorporating this in our platform, however, concluded that this would yield too many complications regarding organization and privacy regulation. A similar limitation was the integration of external health monitoring devices and other health applications with the PRODEMOS application. Due to the variety and rapidly advancing technologies of smartphones and wearable sensors, we could not ensure continued compatibility of these monitoring tools and decided not to integrate them in our mobile application.

The PRODEMOS mobile application was specifically designed for older, vulnerable populations, integrating a simple, intuitive interface, with written and digital instruction manuals and in-person familiarization with the mobile application, guided by the health coach. However, it is conceivable that part of the target population may not be able to overcome some of the technological challenges involved in using the mobile application. Additionally, to use the application, participants need to have regular and affordable access to the internet. Increasing smartphone possession and usage among older adults suggests that this may be a decreasing barrier (27). Until this barrier is completely omitted, mHealth should be complimentary to alternative methods to facilitate behavior change in older adults. Finally, mHealth is a rapidly advancing field, therefore it is important to appraise the reported findings within the context of this changing landscape of innovation, for example by taking new software features and design trends into account (28).

Implications for Future Practice and Research

mHealth may recently have become an even more attractive and desirable way to deliver interventions for risk factor management and disease prevention, as the COVID-19 pandemic has highlighted the need for preventive care that can be accessed remotely. Despite the increasing availability of mHealth applications for the prevention of dementia and cardiovascular disease, studies on the development, implementation, and effectiveness of these platforms are scarce. In order to demonstrate the added value of such technologies, there is an urgent need for evidence-based mHealth interventions and high-quality evaluation studies (29). We believe that when developing such digital interventions, early involvement of end-users and other stakeholders will likely aid success and implementation. Moreover, development of a platform that is sustainably used could benefit from consistency of team members and documentation of all steps and decisions taken during each phase of development.

The actual use and usability of the PRODEMOS intervention will be assessed over the coming years in the PRODEMOS trial, with a dual focus on effectiveness and implementation outcomes. If effective, it likely increases the yield of preventive programs in resource-poor settings. If implementable, it will contribute to an improved understanding how such interventions may be successfully provided in the real-world setting.

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 Health Research Authority (HRA) and Health and Care Research Wales (HCRW) and the Medical Ethics Committee of Capital Medical University (CMU), the Medical Ethics Committee of Taishan Medical University (TSMU), the Medical Ethics Committee of the General Hospital of the People's Liberation Army (PLAGH), and the Medical Ethics Committee of Beijing Geriatric Hospital (BGH). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MH and EE were responsible for the drafting of the manuscript. MH, EE, and MW were responsible for designing included figures. ER, EC, MH-B, CB, and WeiW were responsible for the study conception. ER, EC, MH-B, MS, SA, CB, NC, JG, HM, WenW, YW, AW, and WeiW were responsible for the design of the trial. MH, EE, MH-B, MW, LB, RB, AG, MM, LS, MS, XY, EC, and ER were involved in platform design and development. All authors were responsible for critically revising the manuscript and approved the final version of the 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/fneur.2021.733878/full#supplementary-material

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STUDY PROTOCOL
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HomeCoRe for Telerehabilitation in Mild or Major Neurocognitive Disorders: A Study Protocol for a Randomized Controlled Trial

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Background: Given the limited effectiveness of pharmacological treatments for cognitive decline, non-pharmacological interventions have gained increasing attention. Evidence exists on the effectiveness of cognitive rehabilitation in preventing elderly subjects at risk of cognitive decline and in reducing the progression of functional disability in cognitively impaired individuals. In recent years, telerehabilitation has enabled a broader application of cognitive rehabilitation programs. The purpose of this study is to test a computer-based intervention administered according to two different modalities (at the hospital and at home) using the tools CoRe and HomeCoRe, respectively, in participants with Mild or Major Neurocognitive Disorders.

Methods: Non-inferiority, single-blind randomized controlled trial where 40 participants with Mild or Major Neurocognitive Disorders will be assigned to the intervention group who will receive cognitive telerehabilitation through HomeCoRe or to the control group who will receive in-person cognitive intervention through CoRe, with the therapist administering the same computer-based exercises. The rehabilitative program will last 6 weeks, with 3 sessions/week, each lasting ∼45 min. All the participants will be evaluated on an exhaustive neuropsychological battery before (T0) and after (T1) the intervention; follow-up visits will be scheduled after 6 (T2) and 12 months (T3).

Discussion: The results of this study will inform about the comparability (non-inferiority trial) of HomeCoRe with CoRe. Their equivalence would support the use of HomeCoRe for at distance treatment, favoring the continuity of care.

Ethics and Dissemination: This study has been approved by the Local Ethics Committee and registered in https://clinicaltrials.gov (NCT04889560). The dissemination

plan includes the scientific community through publication in open-access peer-reviewed scientific journals and presentations at national and international conferences.

Trial Registration: Clinicaltrials.gov https://clinicaltrials.gov/ct2/show/NCT04889560 (registration date: May 17, 2021).

Keywords: neurocognitive disorder, dementia, computer-based telerehabilitation, cognitive training, mild cognitive impairment, cognitive rehabilitation

INTRODUCTION

In the light of the limited efficacy of pharmacological therapies for cognitive decline, the management of modifiable risk factors affecting age-associated cognitive decline and risk of dementia is attracting an increasing interest (1, 2). There is some evidence that early cognitive interventions may be effective in individuals in predementia phases (3, 4). Mild cognitive impairment (MCI) (3) or Mild Neurocognitive Disorder according to the *Diagnostic and Statistical Manual of Mental Disorders-5* (DSM-5) (5) is defined as a transitional status between normal aging and possible development of early dementia. It is characterized by subjective cognitive complaints and objective cognitive decline greater than expected for age and education levels of an individual, but not interfering with activities of daily life. Dementia (i.e., Major Neurocognitive Disorder, according to DSM-5), defined according to severity level, is characterized by multidomain cognitive deficits resulting in a significant interference with independence in everyday activities (5).

In this field of research, previous studies demonstrated the effectiveness of cognitive training programs in patients in the early stage (i.e., MCI and mild dementia) of cognitive decline (6, 7). Traditionally, cognitive interventions consist of in-person sessions usually administered in the hospital setting under supervision by a therapist using paper-and-pencil techniques or technology-based solutions. In particular, the use of technology promotes the development of *ad-hoc* (i.e., user tailored) cognitive rehabilitation tools, allowing to overcome the limits associated to paper-and-pencil techniques. Recent advances in technologies allow for a new and innovative implementation of treatments [i.e., telerehabilitation (TR)], which can be easily diffused on large scale and guarantee a continuum of care at distance (4, 8).

Despite the interesting potentialities of TR, several issues are slowing its integration into the clinical routine. A major issue is the poor technological skills of older adults, which may result in difficulties in managing technological devices autonomously (9). Therefore, platforms should be accessible and user-friendly; duration and frequency of rehabilitation activities should vary according to characteristics of the patients (10); therapists should monitor adherence to treatment and outcome of the rehabilitation process remotely (11). There is some evidence (12–17) exploring the usability and acceptability of Information and Communication Technologies (ICTs) in elderly care including participants with dementia or MCI and giving some recommendations for designing interfaces for this kind of users. In general, it resulted that these systems were enjoyable and feasible for participants even if usability not always was high.

However, randomized controlled trials (RCTs) investigating TR efficacy compared to the traditional in-person approaches are still scanty (4). Recently, this topic has gained growing interest, due to the challenges faced by the healthcare systems during coronavirus disease 2019 (COVID-19) pandemic (18–22).

During the past years, we implemented the software CoRe for in-person cognitive training in the hospital setting supervised by a trainer (23, 24). CoRe has been successfully tested in terms of usability and immediate and long-term effectiveness in participants with early cognitive decline (25–27). In light of the improvement in telemedicine approaches and in view of the willingness of treated participants and caregivers to start/continue CoRe program at distance (28), we have developed the "home" version of CoRe (i.e., HomeCoRe) supporting cognitive intervention remotely (29) with the assistance of a family caregiver.

This longitudinal RCT study, thus, aims to evaluate and compare the effectiveness of HomeCoRe and CoRe programs in participants with MCI or mild dementia. Our hypothesis is that cognitive TR delivered via HomeCoRe provides benefits that are comparable to the in-person version of the program on cognitive and behavioral functioning and on additional participant-centered outcomes.

We are currently performing a small-scale usability test on the HomeCoRe system with encouraging results. The first six participants who completed the usability test considered the HomeCoRe system as an innovative and original tool that they integrated smoothly and positively in their daily life routine. These participants are providing us crucial feedback to improve the system usability such as the need of extra time for performing exercises. Based on the feedback received, HomeCoRe is undergoing a refinement process that will lead to the final version to be used in the RCT.

METHODS AND ANALYSIS

Study Design

This study is a prospective single-blind randomized controlled non-inferiority trial. The Consolidated Standards of Reporting Trials (CONSORT) flowchart for enrollment and randomization is shown in **Figure 1**. After recruitment, participants will be contacted and will undergo in-person baseline assessment (T0) using the below-listed tests (see evaluation of the participants section and **Table 1**). Participants who meet the inclusion criteria will be enrolled and randomized to one of two groups: HomeCoRe and CoRe. For both the groups, the intervention will consist of a 6-week program (3 sessions/week, each lasting

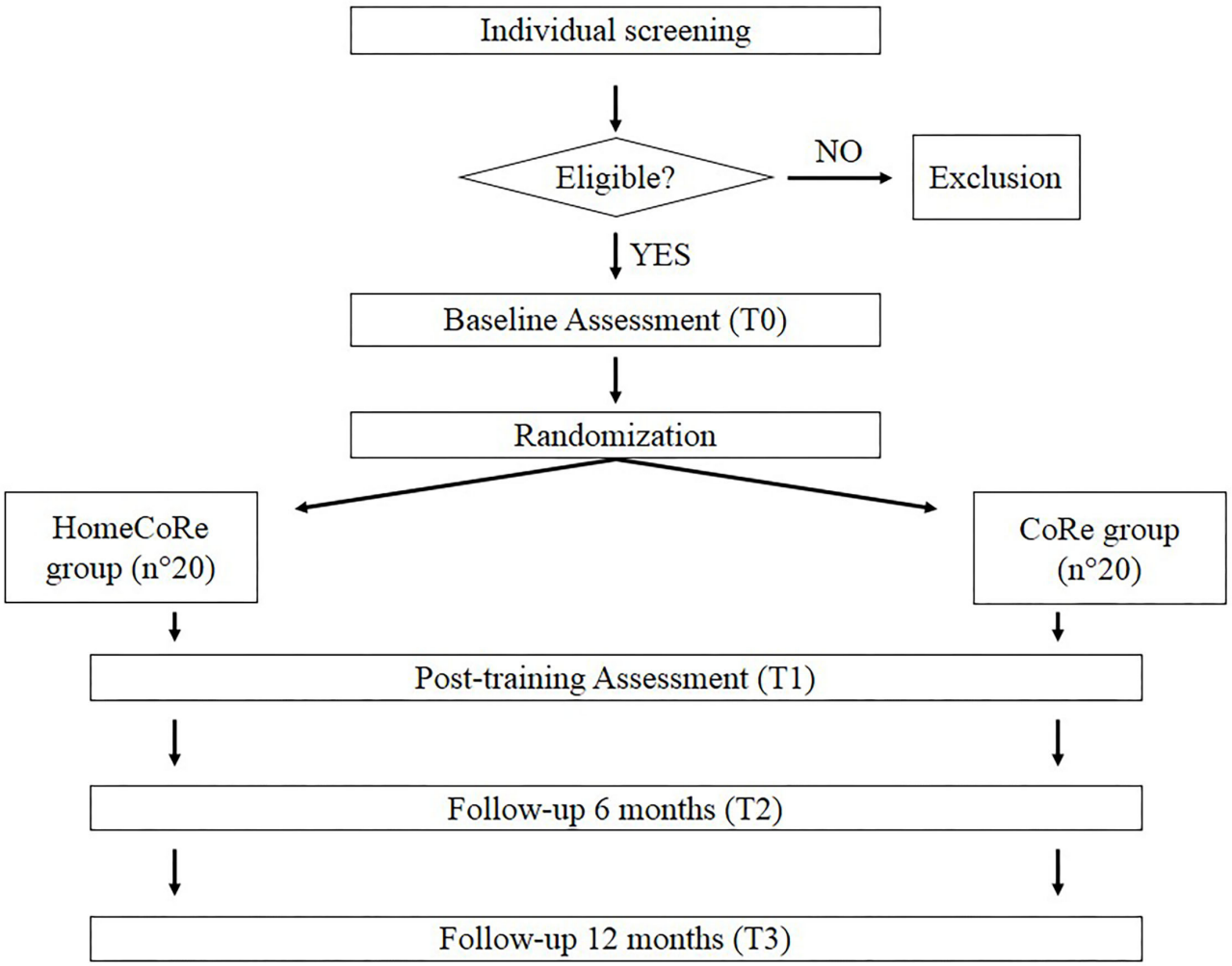

FIGURE 1 | The Consolidated Standards of Reporting Trials (CONSORT) flowchart for enrollment and randomization.

∼45 min). Follow-up in-person neuropsychological assessments will be scheduled at the end of the rehabilitation program (T1) and after 6 (T2) and 12 months (T3).

Data Collection

Assessments will take place at the Scientific Institute for Research, Hospitalization, and Healthcare (IRCCS) Mondino Foundation (Pavia, Italy). Neuropsychologists carrying out evaluations will receive appropriate instruction and guidance regarding all the assessment procedures and outcome parameters. Reminders (e.g., written reminder, phone calls, and email message) for each visit will be given to all the participants. Research staff collecting data will be blind to group allocation. Not all the outcome measures will be administered at each time point (**Table 1**).

Data Management

Study data will be recorded in the database in processes compliant with the General Data Protection Regulation (GDPR). All the participants will be registered with an identification code. The database will be kept updated to reflect the status of the participant at each stage during the course of this study. The collected data, after scientific publication, will be deposited in dedicated repositories (e.g., Zenodo) according to the good practice of data sharing.

Participants and Eligibility Criteria

Participants will be recruited from the Dementia Research Center outpatient services and Neurorehabilitation Unit of the IRCCS Mondino Foundation (Pavia, Italy) and screened for eligibility criteria through a clinician evaluation made by an expert neurologist.

The inclusion criteria for participants will be:

- Diagnosis of Mild or Major Neurocognitive Disorders based on the DSM-5 (5)
- Aged between 60 and 85 years
- Years of education ≥ 5
- Clinical Dementia Rating (CDR) (30) score = 0.5–1.

TABLE 1 | Evaluation battery across testing sessions.

	T0	T1	T2	T3
Neuropsycological assessment				
Global cognition				
Mini-Mental State Examination (MMSE)	x*	x*	x	x
Montreal Cognitive Assessment (MoCA)	x	x	x	x
Episodic long-term memory				
Logical Memory Test immediate and delayed recall	x	x	x	x
Rey's 15 words test immediate and delayed recall	x	x	x	x
Rey Complex Figure delayed recall	x	x	x	x
Logical-executive functions				
Rey Complex Figure copy	x	x	x	x
Raven's Matrices 1947	x	x	x	x
Frontal Assessment Battery (FAB)	x	x	x	x
Semantic fluency	x	x	x	x
Phonological fluency (FAS)	x	x	x	x
Working memory				
Verbal Span	x	x	x	x
Digit Span	x	x	x	x
Corsi's block-tapping test span	x	x	x	x
Attention/processing speed				
Attentive matrices	x	x	x	x
Trail Making Test A and B (TMT)	x	x	x	x
Questionnaires and scales				
Functional level				
Activities of Daily Living (ADL)	x			x
Instrumental Activities of Daily Living (IADL)	x			x
Depressive symptoms				
Beck Depression Inventory (BDI)	x	x	x	x
Health status				
36-Item Short Form Health Survey questionnaire (SF-36)	x	x	x	x
Cognitive reserve				
Cognitive Reserve Index questionnaire (CRIq)	x			
Caregiver distress				
Caregiver Burden Inventory (CBI)$^{+}$	x	x		
Participant-centered outcomes				
Impression of symptom change				
Patient Global Impression of Change (PGIC)		x		
Treatment adherence				
Number of sessions carried out		x		

*T0, baseline assessment; T1, post-intervention assessment; T2, 6-month follow-up; T3, 12-month follow-up. *Is used for the primary outcome, $^{+}$is used only for caregivers of participants with Major Neurocognitive Disorder.*

The exclusion criteria will be:

- Mini-Mental State Examination (MMSE) score < 20
- Presence of cognitive impairment secondary to an acute or general medical disorder (e.g., brain trauma or tumor)
- Presence of severe neuropsychiatric conditions (e.g., mood and behavioral disorders)
- Presence of severe sensory disorder (e.g., deafness or blindness) or motor impairment that prevent trunk control and/or sitting position
- Current cognitive treatments
- Lack of family support for participants with Major Neurocognitive Disorder

Medication intake for dementia and/or past cognitive rehabilitation treatments will be not considered as exclusion criteria given that these factors are not expected to affect the outcome of this study. Any pharmacological treatment ongoing must be stable across the entire period of this study protocol.

Evaluation of the Participants

Table 1 lists the evaluation battery (neuropsychological assessment, questionnaires and scale, and participant-centered outcomes) across testing sessions. Each evaluating session would last about 90 min per participant and will be carried out in a hospital setting.

Neuropsychological Assessment

The cognitive assessment, performed by using neuropsychological tests standardized for the Italian population, will evaluate the following cognitive domains:

- Global cognition:
  - Mini-Mental State Examination (31)
  - Montreal Cognitive Assessment (31, 32)
- Episodic long-term memory:
  - Logical Memory Test for immediate and delayed recall (33, 34)
  - Rey's 15 words test for immediate and delayed recall (35)
  - Rey Complex Figure delayed recall (36)
- Logical-executive functions:
  - Raven's Matrices 1947 (35)
  - Frontal Assessment Battery (37)
  - Semantic fluency (33)
  - Phonological fluency (FAS) (35)
  - Rey Complex Figure copy (36)
- Working memory:
  - Verbal Span (34)
  - Digit Span (34)
  - Corsi block-tapping test span (34)
- Attention/processing speed:
  - Attentive Matrices (34)
  - Trail Making Test A and B (38).

Parallel forms (i.e., alternative versions using similar material) will be applied for follow-up visits when available in order to avoid the learning effect. All the test scores will be corrected for age, sex, and education by using appropriate correction grids and compared with the values available for the Italian population.

Questionnaires and Scales

Additionally, we will administer questionnaires and scales reported below to evaluate the following aspects:

- Functional level:
  - Activities of Daily Living (39)
  - Instrumental Activities of Daily Living (39)
- Depressive symptoms:
  - Beck Depression Inventory (40)

- Health status:
  - 36-item Short Form Health Survey questionnaire (41)
- Cognitive reserve:
  - Cognitive Reserve Index questionnaire (42)
- Caregiver distress:
  - Caregiver Burden Inventory (43) only for caregivers of participants with Major Neurocognitive Disorder.

Participant-Centered Outcomes

In order to assess subjective evaluation of TR success, we will evaluate the following aspects:

- Impression of symptom change:
  - Patient Global Impression of Change (44)
- Treatment adherence:
  - Number of sessions carried out.

Randomization and Stratification

After baseline assessment, we will generate random numbers through the use of a computer algorithm (https://www.random.org/) from a uniform distribution in the range 0–1, dividing the range in two equal intervals and assigning each participant to the group corresponding to the sampled number (1:1 ratio), within strata defined by diagnosis (Mild or Major Neurocognitive Disorders). Neuropsychologists carrying out cognitive evaluations will be blinded to group allocation.

Cognitive Rehabilitation Programs

Both the CoRe and HomeCoRe are research software tools developed within a long-lasting collaboration between clinicians from the IRCCS Mondino and bioengineers from the University of Pavia. At the moment, the tools are limited to Italian speaking participants. The tools allow a participant-tailored intervention aimed at stimulating several cognitive abilities (e.g., logical-executive functions, attention/processing speed, working memory, and episodic memory) through a series of sessions of exercises (see **Table 2** for details). Their use is time-saving for the therapists, as they are ready to use and do not require a continuous manual setting of exercises for each training session. This is because, once the therapist has remotely set up the treatment plan, exercises take place in an adaptive mode across all the sessions. In particular, during their dynamic generation, performance data of an individual participant are analyzed in order to set the appropriate difficulty level. Performance data of the participants refer to the response accuracy normalized according to the number of aids that the participant required to solve the task. Furthermore, for each exercise and each level, thresholds are defined to allow difficulty levels to progressively increase in order to stimulate neural plasticity (6, 45, 46). In addition, the system calculates an overall "Weighted Score" (WS), taking into account the correctness of the answers, the execution time, and the difficulty of the exercises. The WS informs the therapist about each performance of the participant in a single value. Hence, WS represents a useful and advantageous index that can be used to assess both the overall outcome of a training session and the global trend of the rehabilitation (see **Figure 2**).

CoRe/HomeCoRe Software Architecture

Both the CoRe and HomeCoRe require a personal computer equipped with a touch screen. HomeCoRe is installed on a laptop (password protected and encrypted) that is supplied to participants by the therapist, while CoRe is installed on a desktop PC located in the hospital setting. Both the HomeCoRe and CoRe will be installed on the personal computer by an expert engineer and under the supervision of the Information Technology (IT) department—IRCCS Mondino. CoRe, being an in-person treatment, will be then performed under therapist monitoring; HomeCoRe, being home based, will/could be performed under caregiver monitoring. In particular, before the beginning of HomeCoRe treatment, participants and possible caregivers will be trained together at the hospital on the use of the rehabilitation tool at home. This is in order to account for possible differences in baseline technological skills. Then, during the training sessions, participants, with the possible support of their caregivers, will go through each exercise of the treatment until they feel familiar with the use of the device. During the rehabilitative program at home, remote technical support will be available when requested. To this aim, participant will be provided with the support team contacts. The treatment sessions, both in the CoRe and HomeCore, can be paused in case of fatigue of the participant and resumed at a later time.

Differently from CoRe, HomeCoRe architecture includes two main components, namely, therapist side and participant/caregiver side and a communication system (HomeCoRe server). The therapist-side dashboard allows remotely setting and monitoring all the parameters of the treatment plan (e.g., frequency and duration of the plan, type of exercises, difficulty level). The interface of the participant/caregiver is very simple and it allows to view/execute the exercises of the day and to send the results to the therapist (see **Figure 3**).

The HomeCoRe system can be used online or offline in the case that the internet connection of the participant is not available. In the online mode, the communication between the therapist side and participant side takes place automatically through a dedicated communication protocol managed by the HomeCoRe server, while in the offline modality, some manual operations are required for loading the therapeutic plan offline and save result report on an external memory support (e.g., USB key or hard disk). In any case, the communication with the therapist is asynchronous.

Outcome Measures

As the primary outcome measure, we will consider the change in global cognitive functioning, measured using the MMSE at T1 compared to T0. Secondary outcome measures will be longitudinal changes in all the neuropsychological tests, questionnaires and scales (T1, T2, and T3 vs. T0 when applicable according to **Table 1**). Secondary outcome measures will include also participant-centered outcomes to assess those aspects that are most important for the participants and the subjective evaluation of intervention success at T1.

TABLE 2 | CoRe/HomeCoRe description of tasks, reporting involved cognitive skills.

Tasks	Description	Main involved skills
Learning of word pairs	Pairs of words are shown on the screen, the participant is asked to rewrite the second word of the pair when it is shown	Long-term memory abilities; learning and re-enactment strategies; visual imagery
Word categorization	Words belonging to different categories are presented on the screen, the patient is asked to rewrite them in any order but respecting the corresponding category	Long-term memory abilities; learning and re-enactment strategies; visual imagery; categorical thinking
Puzzle	The participant is asked to put together the pieces of a figure to recompose it	Visuo-spatial long-term memory; visual imagery; mental representation and planning
Span backward	The participant is asked to write the numbers in a reverse order compared to what previously heard	Verbal working memory; processing-speed
Memory	After a study phase in which all cards are shown face up, they are faced down. The participant is asked to recall and match all equal cards in the least number of tries, by turning over pairs of cards one by one	Long-term memory abilities; visuo-spatial abilities
Visuospatial matrices	The participant receives a sequence of spatial information (e.g., right, left, up, down) and then he/she is asked to store it and reproduce in the correct order on a grid	Working memory; visuo-spatial abilities; processing-speed
Logical sequences	A sequence of images is shown, the participant is asked to select, among several options, the one that completes the series	Non-verbal reasoning; mental problem solving; decision making
Image and sound	The participant is asked to evaluate right or wrong matching between visual (image size) and auditory (sound volume) stimuli	Inhibitory control; processing-speed; working memory
Sentence recomposing	The participant is asked to put scrambled words in the correct order to form a full sentence	Mental and verbal planning; conceptual abstraction abilities
Story recomposing	The participant is asked to reorganize a scrambled sequence of images in the right chronological order to form a short story	Planning of activities: problem solving; temporal sequencing; visual attention
Recognition exercise	The participant is asked to identify and select specific items within a matrix of random elements (letters or numbers)	Sustained and selective attention; visuo-spatial scanning; processing-speed

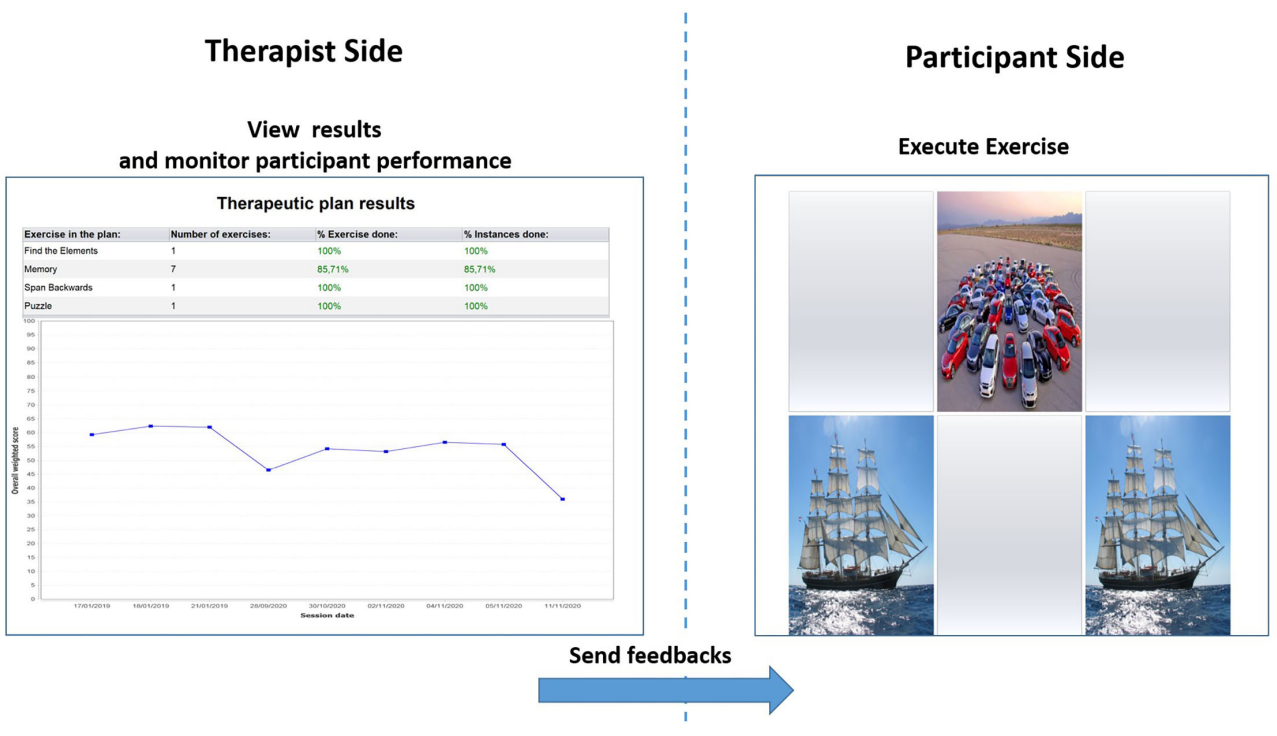

FIGURE 2 | Therapist interface for monitoring performances of the participant in terms of overall Weighted Score (left) and interface of the participant for the execution of exercises (right).

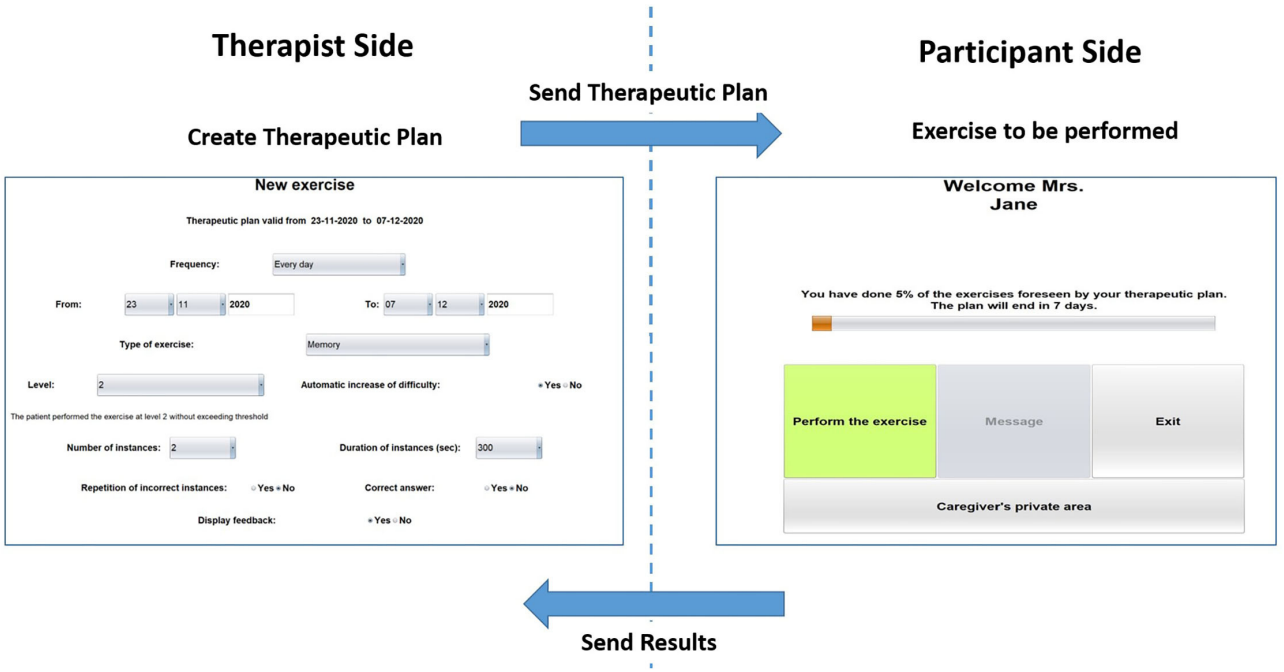

FIGURE 3 | Home page of the therapist side of the interface for setting the requirements for the exercise plan (left) and home page of the participant/caregiver side of the interface (right) for HomeCoRe.

Statistical Analysis

Sample Size Calculation

Sample size has been estimated based on previous evidence in the literature (47). Since this is a non-inferiority study, we will consider as margin d a value of two points difference (T1 vs. T0) at the MMSE between the two groups. We predict to obtain a mean difference between HomeCoRe and CoRe groups of about one point at the MMSE with an SD of 1. Considering an alpha significance of 0.05 and a power of 0.9, the sample size for a non-inferiority study is 18 participants per group, for a total of 36 participants. It is planned to enroll a total of 40 participants in order to account for possible dropouts. If dropout rates between T0 and T1 will be higher than expected, extra participants will be recruited. The sample size for non-inferiority studies was calculated using R 4.0.2 software, SampleSize4ClinicalTrials package.

Planned Analysis

Statistical analysis on outcome measures will be conducted using the SPSS software (see **Supplementary Materials** for planned analysis). A normality test will be used to assess the distribution of all the outcome measures. Baseline differences between groups will then be tested using the independent samples t-test for parametric data and the Mann–Whitney U-test for non-parametric data. Within-group statistical tests will be performed for both the CoRe and HomeCoRe groups to look for significant changes in primary and secondary outcome measures over time. Between-group tests will be performed to look for differences in primary and secondary outcome measures between HomeCoRe and CoRe participants. Possible between-group differences in demographic and clinical characteristics (e.g., age, sex, years of education, diagnosis, and cognitive reserve) and in T0 scores in primary and secondary outcome measures will be considered as possible confounders and will be treated as covariates in the analysis. $p \leq 0.05$, corrected for multiple comparisons, if appropriate, will be considered as statistically significant.

Ethical Issues

This study will involve human participants, cognitive rehabilitation interventions, data collection, elaboration, and abstraction used for the evaluation of the two therapeutic options. In addition to ethical approval, all the procedures and the data managed have been approved by the Data Protection Officer of the IRCCS Mondino who guarantees compliance to the GDPR. The information provided when presenting the informed consent to the participants will be given in a language appropriate to the individual level of understanding. Participants will also be encouraged to ask questions before signing the informed consent.

To the best of our knowledge, HomeCoRe should not have any potential negative impact on the participant. The investigator will communicate any possible, unforeseen, and adverse event to the Ministry of Health. With respect to payment policies for participants, the amount of compensation and the method and timing of disbursement must be consistent with the laws, regulations, and guidelines of the region in which this study is conducted and must not improperly influence a decision of the participant to participate. This study is a no-profit study and, in

Italy, the national legislation refers that it is forbidden to offer or request any kind of financial benefit for the participation in a clinical experimental trial.

Since participants are expected to interact with a rehabilitation tool (the HomeCoRe application), one possible issue could be frustration in case of lack of ability to cope with that technology. However, this risk will be mitigated, before the beginning of HomeCoRe treatment, thanks to specific training sessions on the use of this application that will be delivered to participants (and possible caregivers) (see CoRe/HomeCoRe software architecture section). Moreover, the interface fully complied with the guidelines for human–computer interaction, to make the user interface as easy as possible.

DISCUSSION

Due to the increase of the aging population, we are witnessing a steady increase in the number of older adults at risk of developing cognitive decline with a consequent increase of economic burden on healthcare. Therefore, the WHO Global Action Plan on the Public Health Response to Dementia 2017–2025 recommends taking global action against cognitive decline and dementia, encouraging governments worldwide to focus on prevention and improving healthcare services (48). Telemedicine is defined as an interface in a virtual patient–clinician relationship to provide primary and secondary care by adopting innovative solutions reaching larger groups of participants (49). Telemedicine can be considered as an adaptation of the healthcare model based on in-person interaction, according to the characteristics and needs of the participants (50). In particular, TR is a telemedicine subfield aimed at providing rehabilitation at a distance (51). TR provides benefits for the healthcare system, patients, and caregivers in terms of cost-effectiveness and feasibility for large-scale implementations (52–54). It represents a replacement for in-person treatment or its continuation, favoring equitable access to care not only for older patients with dementia or physical disabilities, but also for subjects of working age or living in geographically remote areas in predementia phases. Hence, TR is a unique opportunity in the field of cognitive rehabilitation to guarantee constancy and continuity to cognitive training programs.

The results of this trial will inform about the comparability of HomeCoRe with CoRe system. In case they will result equivalent, such a finding would support the use of HomeCoRe in the treatment of patient at distance, with the consequent multiple positive impacts mentioned above. In this framework, HomeCoRe could be incorporated into clinical routine practices as a complementary non-pharmacological therapy to contrast cognitive impairment and dementia. In case HomeCoRe will prove less effective than CoRe, it would lead to the conception of telerehabilitation as a compromise that must be made under particular conditions such as in case of emergency [i.e. coronavirus disease 2019 (COVID-19) pandemic] or personal needs (e.g., travel difficulties).

Strengths and Limitations

This RCT will allow to implement and assess the effectiveness of a TR tool targeting participants with cognitive decline. HomeCoRe aims to provide participant-tailored cognitive intervention directly at home, also when needed to extend the duration of cognitive programs started in the hospital setting and to reduce the dropout rate. The availability of effective and feasible TR modalities will address the paucity of healthcare personnel dedicated to cognitive rehabilitation within the neuropsychology services, thus increasing the offer to a wider population. It will also provide a modality to ensure care continuity also during COVID-19 pandemic crises.

This study has some limitations that need to be acknowledged. In particular, participants with scanty computer familiarity and without a compliant caregiver could be excluded by the use of TR, representing a selection bias for this kind of intervention (55). However, there is also evidence about the possibility of using telemedicine devices in participants with early cognitive impairment living alone. It seems that compliance of the participants depends on the level of monitoring remotely received (56). In addition, it is important to consider that user-friendly developed TR tools can produce benefits in participants and also caregivers (57).

ETHICS STATEMENT

This study has been approved by the Local Ethics Committees (IRCCS San Matteo Hospital, Pavia) and will be conducted in accordance with the Declaration of Helsinki and reported according to the CONSORT guidelines (58, 59). The trial was registered at clinicaltrials.gov (NCT number: NCT03486704). All the participants will be made fully aware of the aims of this study and a written informed consent will be obtained from all the subjects.

AUTHOR CONTRIBUTIONS

SBe and SBo developed the original concept of the study, drafted the original protocol, and wrote the manuscript. SBe, SBo, SQ, SP, and ES developed the design, the methodology, and the analysis plan. SQ, SP, ES, SFC, CC, TV, and CT reviewed and commented on drafts of the protocol and study. All authors read 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/fneur.2021.752830/full#supplementary-material

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Information Communication Technology as Instrumental Activities of Daily Living for Aging-in-Place in Chinese Older Adults With and Without Cognitive Impairment: The Validation Study of Advanced Instrumental Activities of Daily Living Scale

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Background: The capability in applying information communication technology (ICT) is crucial to the functional independence of older peoples of community living nowadays. The proper assessment of individuals' capability of ICT application is the corner stone for the future development of telemedicine in our aging population.

Methods: With the recruitment of 300 participants of different functional and social background in home-living, hostel-living, and care-and-attention home living; and through assessing the ability of individuals in instrumental activities of daily living and cognitive assessments, this study aimed at capturing the content validity and construct validity of the Advanced Instrumental Activities of Daily Living (AIADL scale). In addition, this study assess the ability of older peoples in applying ICT and how the functional and social background affects their independence in aging-in-place.

Results: The AIADL scale showed good test-retest reliability and good-to-excellent internal consistency. To determine if items of the AIADL scale measure various aspects of community living, exploratory factor analysis revealed a two-factor structure with "home living and management" and "community living". Validity analysis with the known-groups method showed a high overall accuracy of prediction of individuals' capability of independent living in the community.

Conclusions: The AIADL scale is a valid and reliable instrument to assess the ability of older adults in handling ICT as part of their instrumental activities in daily living. The

scale can reflect capability of older peoples in applying ICT. This instrument can serve as a reference in measuring readiness of individuals in receiving telemedicine and their ability of aging-in-place.

Keywords: information communication technology, instrumental activities of daily living, aging-in-place, older adults, telemedicine

BACKGROUND

Activities of daily living (ADL) describe basic but essential everyday activities of self-care, such as bathing, dressing, and feeding (1). Instrumental activities of daily living (IADL) describe activities necessary for adaptation to the environment and emphasize community activities, such as shopping, cooking, transportation, and other types of activities including housekeeping. These activities are key life tasks that older adults need to manage to live in the community and be functionally independent (2, 3). The activities of IADL are more cognitively influenced (4) and are important parameters for successful aging in place of older adults (5, 6). Advanced activities of daily living (AADL), on the other hand, represent activities that involve superior cognitive abilities along with adequate physical and social functioning that could enable an individual to maintain his or her own self-identity through the development of various social roles, such as event-planning and participation within the community (7). Occupational therapists play an important role in assisting older adults to overcome functional decline of individuals and support engagement of their own life roles in the community (8). Reflecting on the fact that information communication technology (ICT) is becoming an increasingly inseparable part of our modern lives, we have further coined the term advanced instrumental activities of daily living (AIADL) as IADLs that have taken into account the technological competencies necessary for independent living within today's community.

The Lawton Instrumental Activities of Daily Living (Lawton IADL) scale is a well-known and classical instrument in assessing the independent living skills of individuals (9–11). Due to its easier apprehensible and less time demanding in administration (11, 12), the Lawton IADL still outweighs more recently developed IADL measures, such as the Assessment of Living Skills and Resource (ALSAR) (13, 14). The Lawton IADL has been cited by over 3,000 published studies (11) and has considerable evidence of its reliability and concurrent validity (15, 16). Its Chinese version, namely the Lawton Instrumental Activities of Daily Living—Chinese Version (IADL-CV) was validated in 2002 using data from 155 older adults living in homes for the aged and care-and-attention homes (16). The IADL-CV consists of nine items: use of telephone, transportation, shopping, medication management, money management, meal preparation, housework, laundry, and handyman work. It was shown to be a reliable instrument for assessing the ability of older adults to live independently in the community. With the use of the known-groups method, the IADL-CV had been validated with a one-factor structure (16). However, the psychometric properties of IADL-CV have not been further examined in the past decades and it does not measure ability of individuals in applying ICT (13).

Applied technology, such as the use of ICT and smartphone applications, has had a huge impact on the world and on lifestyles of individuals. Ability in handling these technologies is not only considered essential for daily functioning but also plays a role in formulating an individual's sense of independence in the community, thus increasing the quality of life of an individual (17, 18). This ability is getting more and more common in the contemporary digitalized world (19, 20) and regarded as a core essential skill for the older people (21–24) and has been regarded as the corner stone for the development of telemedicine in dementia care and treatment (21, 22). Due to the huge gap of existing daily living measurement tools, such as the Lawton IADL and the IADL-CV, which had not been designed to cater for the currently technologically heavy times (13, 15, 25), we should therefore have an instrument in place that can evaluate functions of individuals in the contemporary community nowadays.

This study aimed at assessing the ability of older adults' ICT application, and how their functional and social background affects the independence of individuals in aging-in-place and to capture the content validity and construct validity of the Advanced Instrumental Activities of Daily Living (AIADL scale). Instead of sacrificing the already established psychometric properties of the IADL-CV that had developed its framework from the well-known Lawton IADL, this study enriched the content of the IADL-CV by adding to it the relevant items involving ICT and smartphone applications for engaging in IADLs nowadays, creating an updated instrument called the AIADL scale that can capture the technological aspect of everyday living of the Chinese older people. In validating the AIADL, the classical test theory was adopted (26, 27) to examine and test (1) the degree of clarity, understandability, and relevance (i.e., content validity), (2) the test-retest reliability score of the AIADL scale, (3) the degree of the inter-relatedness among the AIADL scale items, such as internal consistency, (4) the factor structure of the AIADL scale by exploratory factor analysis, (5) the correlation between the Lawton IADL score and the AIADL scale measure, and (6) to determine the construct validity and by using the AIADL scale to predict the residence of older adults

Abbreviations: AIADL, The Advanced Instrumental Activities of Daily Living; AIADL scale, The Instrument of Advanced Instrumental Activities of Daily Living; IADL, The Instrumental Activities of Daily Living; Lawton IADL, The Lawton Instrumental Activities of Daily Living; ALSAR, The Assessment of Living Skills and Resource; IADL-CV, The Lawton Instrumental Activities of Daily Living—Chinese Version; HK-MoCA, The Hong Kong Montreal Cognitive Assessment; CDAD, The Chinese version of the Disability Assessment for Dementia; HL, Participants who were Home-Living; HE, Participants from Hostels for the Older People; C&A, Participants from Care-and-Attention Homes.

with known-groups method [in parallel with the method adopted by the validation of IADL-CV (16)].

METHODS

Participant Selection and Ethics Consideration

To ensure generalizability of the research findings that apply to older people in the community, participants were recruited from members of several day activity centers located in six different districts in Hong Kong. These participants included home-living participants (HL) who are functionally and socially independent community dwellers living in their own homes, hostel-living participants (HE) who are independent in terms of self-care and community living but with a need for social support, and care-and-attention home living participants (C&A) who need environmental support as well as assistance with their daily functioning. A total of 100 participants were recruited through purposeful sampling from a local non-government organization through an advertisement and all of them had to complete the MoCA-HK, the CDAD, Lawton IADL, and the AIADL scale questionnaires. In examining test-retest reliability of the AIADL scale, the HL group was asked to fill out the AIADL scale again 1 week later. In analyzing the factor structure, performances of both the HL and the HE group on the tests were used so as to conduct an exploratory factor analysis. Finally, in exploring the group differences among the three groups, known-group analysis was employed to compare the performances of groups on the MoCA-HK, the CDAD, the Lawton IADL, and the AIADL scale.

Prior to their participation in this study, written consents were sought from every participant with their first-degree relatives as witnesses. The inclusion criteria were: (a) ages between 65 and 80 years inclusive, which covered more than 80% of the older people in Hong Kong, (b) the ability to understand verbal and written Chinese instructions, and (c) the ability and willingness to provide written consent and sign the relevant document. The following exclusion criteria were applied: (a) participants with a history of substance abuse, such as alcohol, drugs, or any medication/substances indicative of chronic abuse, so as to prevent any possible craving behaviors from occurring that could lead to biased results; (b) participants with major neurological disorders, such as stroke and head injury, which could have a more direct impact on their IADL performances. Approval was given by the university research ethics committee and the study was conducted according to the Declaration of Helsinki.

Measurements

The items of the AIADL scale were initially developed by a panel of experts. The panel then reviewed the items content and cultural relevance of these items and explore how these were relevant to aging. The experts in the panel, who have experience of more than 20 years in the frontline domiciliary healthcare services, examined each item in the IADL-CV. The panel used the tailor-made questionnaire to evaluate the relevance of the IADL-CV to IADL for community-living older adults. The relevance of each item was assessed by a self-reported questionnaire using a visual analog scale ranging from 1 to 10 (1 = no relevance; 10 = cultural relevance). The panel agreed that a score of <7 indicated that an item may not be relevant. Panel members recommended that the item on the adoption and handling of ICT should be added to measure ability of individuals in community living. Additionally, the concept of using stored value smart card for electronic payments should be added for money management. With the modification of the IADL-CV items, the AIADL scale is a 10-item instrument to be used in assessing the IADLs of older people in the community. These ten items include use of information communication technology (in accessing the internet to obtain information), use of landline telephone, transportation, shopping, medication management, using electronic payments and money management, meal preparation, housework, laundry, and handyman work. The score ratings are from 0 – dependent, 1 – with help to 2 – independent, accumulatively ranging from 0 to 20. Higher scores indicate higher levels of functional independence in performing IADLs. Additionally, the cognitive function of individuals was screened using the Hong Kong Montreal Cognitive Assessment (HK-MoCA) (28), scoring 19 or less would be classified as having cognitive impairment. Furthermore, the physical disability and executive function of individuals were assessed by the Chinese version of the Disability Assessment for Dementia (CDAD) (29), their ability in instrumental activities of daily living Lawton IADL score (9). These were used to assess the convergent validity of the AIADL scale, as the both CDAD and Lawton IADL has been well recognized for the "golden" measurement of individuals' instrumental activities of daily living (29).

Statistical Plan

The AIADL scale was tested for its degrees of clarity, understandability, and relevance. Moreover, kappa coefficient was used in interpreting the degree of agreement of expert panels for these items on the AIADL scale. The content validity and cultural relevance of the AIADL scale were measured by the content validity index. In construct validation, there are three different groups of participants. HL participants who are independent dwellers living in their own homes. HE participants who are independent in terms of self-care and community living but with social support needs. These two groups of participants provided their self-ratings on the AIADL scale. C&A dwellers need environmental support and assistance in IADL tasks. HL and HE participants self-completed the AIADL scale while C&A participants were helped by the interviewer in completing the AIADL scale. The recruitment of participants is as shown in the flow diagram in **Figure 1**.

Demographic information, socio-demographic, and health history were collected through the membership registration of the NGO. Data analyses were conducted using IBM-SPSS (version 23) on Windows 10 operating system (OS). Standard descriptive statistics were computed for continuous data and frequency distributions for non-continuous data. The Shapiro–Wilk test was used to check whether or not a continuous variable follows a normal distribution. Parametric analysis would be employed as far as possible, with data transformation to better comply with mathematical assumptions of parametric analysis whenever appropriate. Statistical significance of 0.05 would

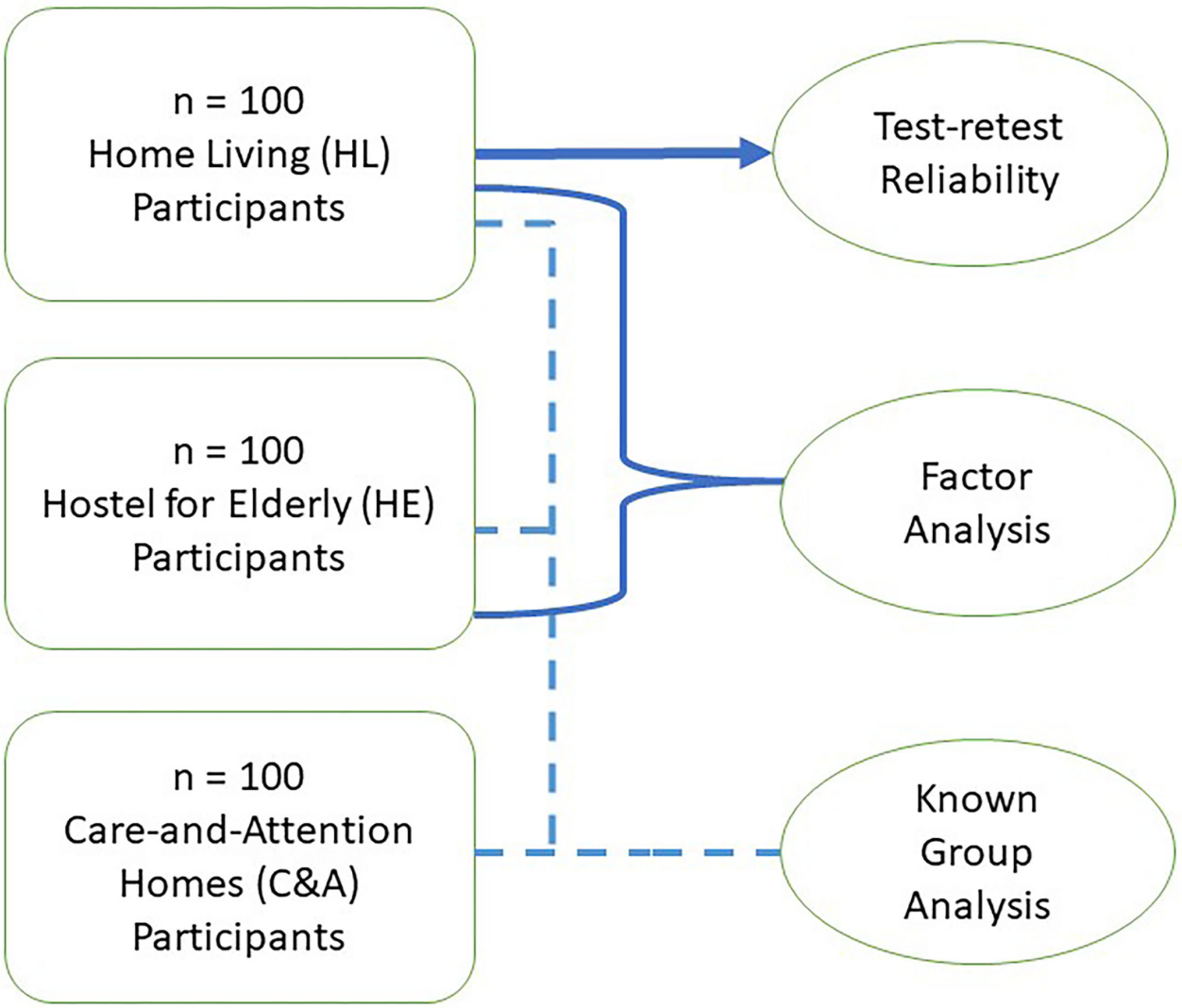

FIGURE 1 | Flow diagram to demonstrate recruitment of participants.

be applied throughout. The intra-class correlation coefficient (ICC) would measure the reliability and internal consistency, by two-way mixed-effects model and absolute-agreement model, of ratings on the AIADL scale. We used chi-square tests to compare the frequency distributions between the different groups of participants. For construct comparison, Pearson's correlation coefficients were computed to compare scores on cognitive (HK-MoCA) and functional disability and executive function (CDAD) and instrumental activities of daily living (Lawton-IADL) parameters. To compare if there was any difference among the three groups, ANOVA comparison and *post-hoc* analysis of cognitive function and the AIADL scale mean scores among these groups were conducted. Moreover, in determining if items of the AIADL scale measure various aspects of community living of the participants who are independent in respect of community living, the exploratory factor analysis using a principal-axis factor extraction was conducted to determine the factor structure of the AIADL scale. Bartlett's test of sphericity was used to test if the correlation matrix was an identity matrix, which indicated variables are unrelated and therefore unsuitable for structure detection. Statistical significance of 0.05 indicated that factor analysis could be useful. The Kaiser-Meyer-Olkin (KMO) test was used to determine the sampling adequacy of the data that were used for factor analysis. Validity analysis by the known-groups method was used to predict the accuracy of their residence in the community (16).

Sample Size Estimation

Power analysis was performed using G*Power based on the previous reference study of the IADL-CV (16) and calculated with a medium effect size = 0.4, statistical significance = 5%, and estimated power = 0.8. G*Power indicates that the

required sample size per group is 84 for test-retest reliability in older people who are independent in community-living. Each participant was asked to complete the AIADL scale two times, the interval between the two measures was 1 week for test-retest reliability. For factor analysis of independent community-living older people, the present exploratory factor analysis used in determining the factor structure of the AIADL scale fulfilled the "old school" theory on the number of cases per variable (N/p), with recommended ratios ranging from 3:1–6:1 (30) to 20:1 (31). In particular, Hair and colleagues had advised researchers to obtain the highest cases-per-variable ratio possible to minimize the chance of overfitting the data. Therefore, ninety participants per group for HL and HE were required in producing small to medium effect size = 0.3. Taking 10% attrition rate, 100 HL and 100 HE participants were recruited. Another 100 functionally dependent participants from C&A were recruited for validity analysis by predicting the social group through using the known-groups method.

RESULTS

Content Validity of the AIADL Scale

To assess content validity of the AIADL scale, 10 Chinese-speaking HL older people (6 women and 4 men; ages ranged from 65 to 75 years, mean = 68.76 years, SD = 2.76) were recruited from a day activity center to complete a survey. The education of participants ranged from primary to tertiary levels with the mean of the participants' education levels with 8.32 years. The panel of experts consisted of five members (three occupational therapists and two community nurses) with experience of more than 20 years (with mean 20.23 years) in domiciliary healthcare and they actually used these tools in their line of work. After revealing the feedback in the survey, panel members discussed all items of the AIADL One item on adoption and handling of ICT was added to the AIADL scale. Additionally, the concept of using stored value smart card for electronic payments was refined under the category of money management, so as to increase the comprehensibility and relevance to money management nowadays. All ten items showed satisfactory clarity and understandability of presentation in the AIADL (with a mean score > 7 out of 10) except the item on handyman work which scored 6.82 out of 10 (SD = 0.29). This was referred back to the panel for further discussion and confirmed to be retained.

For the panel survey, the kappa score was used to indicate the level of agreement of item and content of AIADL between the panel members. As depicted in **Table 1**, all items of the AIADL scale result with the Kappa score range from 0.61 to 0.75, which indicate that there are moderate to substantial agreement of items among the AIADL scale (32). Moreover, all of the item-level content validity index (I-CVI) indicated the item-level content validity ≥ 0.81, and the scale-level content validity index based on the average method (S-CVI/Ave) = 0.83 indicated good content validity and cultural relevance of the new AIADL scale.

TABLE 1 | Agreement of items by expert panel ($n = 10$).

Item of AIADL	Kappa score (95% confidence interval)	I-CVI (item-level content validity index)
1. Use of telephone	0.75 (0.43–0.95)	0.83
2. Use of information communication technology (*new item)	0.74 (0.42–0.94)	0.81
3. Transportation	0.72 (0.45–0.89)	0.86
4. Shopping	0.68 (0.46–0.92)	0.81
5. Meal preparation	0.66 (0.47–0.93)	0.86
6. Housework	0.71 (0.46–0.92)	0.81
7. Handyman work	0.65 (0.43–0.95)	0.84
8. Laundry	0.67 (0.38–0.86)	0.84
9. Medication management	0.62 (0.41–0.87)	0.82
10. Money management (#refined item)	0.62 (0.43–0.82)	0.83

Test-Retest Reliability of the AIADL Scale Assessment

The characteristics of these three groups are depicted in **Table 2**. Since we had a relatively large sample size and a Shapiro–Wilk test was performed and did not show evidence of non-normality (W = 0.92, $p = 0.11$; W = 0.79, $p = 0.35$; W = 0.86, $p = 0.55$ in HL, HE, and C&A, respectively). Based on this outcome, and after visual examination of the histogram of the QQ plot, we decided to use a parametric test.

In test-retest reliability analysis, 100 participants from the HL group (65 women and 35 men; ages ranged from 65 to 75 years, mean = 69.71 years, SD = 2.58) were recruited. They had a MoCA score of mean = 23.89, SD =1.65, the CDAD score of mean = 0.92, SD = 0.03. The Lawton IADL score of mean = 16.34, SD = 0.23. These scores indicated these group of participants were having intact cognitive functions. The AIADL scale was repeated 1 week after the pre-test by the 100 participants. The ICC and 95% *CI*s were calculated on the basis of two-way mixed-effects model. There was good test-retest reliability with an ICC of 0.88 from the AIADL scale summation score (individual item ICCs ranging from 0.86 to 0.92, and 95% *CI*: 0.84–0.95) as shown in **Table 3**. There was good to excellent internal consistency (Cronbach's alpha = 0.94).

Factor Analysis of the AIADL Scale

In analyzing the factor structure, apart from the 100 HL independent community-dwelling participants that were recruited initially, another 100 independent community living HE participants (53 women and 47 men; ages ranged from 67 to 77, mean = 68.34, SD = 1.47; with MoCA score with mean = 23.72, SD = 1.39, CDAD score with mean = 0.91, SD = 0.03, and the Lawton IADL score of mean = 15.78, SD = 0.32) were recruited. The mean score of the AIADL scale of the HL group was 19.52 (SD = 1.26) and the HE group was 19.48 (SD = 1.21). There was good linear relationship between individual items

TABLE 2 | Characteristics of recruited subjects.

	Female (*n*)	Male (*n*)	Age range (mean ± SD)	MoCA (mean ± SD)	CDAD (mean ± SD)	Lawton IADL (mean ± SD)	AIADL (mean ± SD)
Home-living participants (HL)	65	35	65–75 (69.71 ± 2.58)	23.89 ± 1.65	0.92 ± 0.03	16.34 ± 0.23	19.52 ± 1.26
Hostel-living participants (HE)	53	47	67–77 (68.34 ± 1.47)	23.72 ± 1.39	0.91 ± 0.03	15.78 ± 0.32	19.48 ± 1.21
Care-and-attention home living participants (C&A)	45	55	66–80 (71.23 ± 7.38)	14.29 ± 2.19	0.42 ± 0.09	11.21 ± 0.23	13.28 ± 2.84

TABLE 3 | Reliability testing of the AIADL scale ($n = 100$, home living participants).

Items of AIADL	Test-retest reliability (ICC) ($n = 100$)
1. Use of telephone	0.90 (95% C.I. = 0.89–0.91)
2. Use of Information communication technology (*new item)	0.86 (95% C.I. = 0.84–0.91)
3. Transportation	0.91 (95% C.I. = 0.86–0.94)
4. Shopping	0.91 (95% C.I. = 0.85–0.95)
5. Meal preparation	0.90 (95% C.I. = 0.86–0.91)
6. Housework	0.92 (95% C.I. = 0.87–0.93)
7. Handyman work	0.90 (95% C.I. = 0.88–0.91)
8. Laundry	0.92 (95% C.I. = 0.89–0.93)
9. Medication management	0.89 (95% C.I. = 0.84–0.91)
10. Money management (#refined item)	0.88 (95% C.I. = 0.86–0.93)

on the AIADL scale (Pearson's *r* ranging from 0.72 to 0.91), item-factor correlation with Pearson's *r* ranged from 0.78 to 0.90, and item-total correlation ranged from 0.79 to 0.89. To test for the correlation matrix of variables, Bartlett's test of sphericity was used to establish the adequacy of the dataset. All items on the AIADL scale showed a p of <0.05. KMO measure of sample adequacy showed with 0.82, which indicated a factor analysis that would be useful with the collected data.

Category quantification was applied to treat the levels of the trichotomized data directly as values from a continuous distribution. The exploratory factor analysis using a principal-axis factor extraction was conducted to determine the factor structure. Direct oblimin rotation methods were used and created two factors with sums of squared loadings ranging from 0.72 to 0.81. Two dimensions were yielded from the factor analysis, their loading is depicted in **Table 4**. The first dimension had an Eigen value of 3.95 (with 95% *CI* from 2.47 to 4.21) which contributed 45.60% of the variance; the second dimension had an Eigen value of 1.98 (with 95% *CI* from 1.21 to 3.21), which contributed 39.92% of the variance.

Upon thorough discussions among the expert panel and the research team, factor one was labeled "home living and management," which represented IADL tasks that are typically performed within the household, and included six items: use of telephone, meal preparation, housework, handyman work, laundry, and medication management. Factor two was named as "community living," which represented other IADL tasks that are generally done within the community outside the household, and consisted of four items: transportation, shopping, money management, and use of mobile electronic communication devices. The ranges of item total correlation were from 0.75 to 0.82 (for "home living and management"), and 0.71 to 0.83 (for "community living"). In measuring the internal consistency of these two individual factors and the overall AIADL scale, the Cronbach's alphas were 0.96, 0.94, and 0.94, respectively. The high internal consistency suggests that the two factors and the overall AIADL scale measure the same construct. Moreover, the Lawton IADL showed higher correlation with the AIADL scale ($r = 0.87$, $p < 0.01$), with "Home living and management" factor ($r = 0.89$, $p < 0.01$), and "Community Living" factor ($r = 0.73$, $p < 0.01$). The distribution of items' score is depicted in **Table 4**.

Examine Group Difference From Three Types of Residences

In examining if there were group differences, apart from the HL and HE participants, we recruited another 100 C&A participants, 45 women and 55 men, with ages ranging from 66 to 80 years (mean = 71.23, SD = 7.38); MoCA score with mean = 14.29, SD = 2.19, CDAD score with mean = 0.42, SD = 0.09 and the Lawton IADL score of mean = 11.21 ± 0.23. Their AIADL scale score was 13.28 (SD = 2.84).

In accordance with the methodology in validating the IADL-CV (16), by using the known-groups method, the AIADL scale was used to predict participants into their corresponding living institutions, i.e., HL, HE, and C&A homes. **Table 5** shows a high accuracy of older adults' residence in the community (91.67%). This figure came from concordant pairs (92 + 88 + 95)/300. The correlation coefficient between the AIADL scale scores and known group was 0.85, a correlation matrix was constructed using the cognitive functions of participants and factors of the AIADL scale. Cognitive function showed a significant correlation with home living and management ($r = 0.78$, $p < 0.001$), and with community living ($r = 0.72$, $p < 0.01$).

A one-way ANOVA among the subjects was conducted to compare the effect of groups on AIADL and cognitive conditions. There was a significant effect of grouping on AIADL at the $p < 0.05$ level for the three groups [$F_{(2,297)} = 202$, $p = 0.03$]. A *post-hoc* comparison using the Tukey's honesty significant difference (HSD) test indicated that the mean score for the C&A group (M =13.28, SD = 2.84) was significantly different from the HL and HE group (M = 19.52, SD = 1.26 and M = 19.48, SD = 1.21, respectively). Similarly, there was a significant effect of grouping on cognitive function at the $p < 0.05$ level for the three groups [$F_{(2,297)} = 189$, $p = 0.03$]. A *post-hoc* comparison using the Tukey's HSD test indicated that the mean score for the

TABLE 4 | Factor loading of the AIADL scale [$n = 100$, home living (HL) and $n = 100$, hostel for older people (HE)].

Items of AIADL	Item scores (HL)	Item scores (HE)	Factor 1	Factor 2
1. Use of telephone	1.81 ± 0.12	1.80 ± 0.11	0.72	0.11
2. Use of information communication technology (*new item)	1.67 ± 0.23	1.65 ± 0.18	0.17	0.72
3. Transportation	1.67 ± 0.23	1.66 ± 0.21	0.12	0.72
4. Shopping	1.63 ± 0.23	1.63 ± 0.21	0.12	0.72
5. Meal preparation	1.72 ± 0.09	1.72 ± 0.11	0.81	0.07
6. Housework	1.34 ± 0.42	1.34 ± 0.41	0.72	0.12
7. Handyman work	1.47 ± 0.39	1.47 ±0.38	0.72	0.21
8. Laundry	1.62 ± 0.23	1.63 ± 0.32	0.72	0.09
9. Medication management	1.67 ± 0.21	1.65 ± 0.22	0.77	0.12
10. Money management (#refined item)	1.72 ± 0.23	1.71 ± 0.23	0.11	0.72
Total score	19.52 ± 1.26	19.48 ± 1.21		

Confidence intervals (CIs) for eigenvalues

Factor number	Observed eigenvalue	95% CI
1	3.95	(2.47–4.21)
2	1.98	(1.21–3.21)

C&A group (M =14.29, SD = 2.19) was significantly different from the HL and HE group (M = 23.89, SD = 1.65 and M = 23.72, SD = 1.39, respectively). However, there was no significant difference in both AIADL and cognitive functions from HL and HE participants.

In convergent validity, the score of the AIADL scale had a high correlation with the cognitive construct- the MoCA-HK ($r = 0.86$, $p = 0.02$), and the functional construct -the CDAD ($r = 0.85$, $p = 0.01$); the Lawton IADL ($r = 0.96$, $p = 0.01$). The AIADL scale was shown to be reliable and valid in assessing the daily function of community-residing older adults.

DISCUSSION

Aging in place is a process that involves both the person and the environment; it is a continuous dynamic interaction as both the person and the environment changes. With the influence of ICT, our living environment has changed substantially (20, 25). Rehabilitation practitioners should be sensitive to the changing environment, cultural, and social factors over time. ICT, such as smartphone application or other mobile electronic devices (33), use of stored value smart cards for making electronic payments (34), and Internet browsing are considered essential for older adults in the community nowadays (15). Nevertheless, this trend of daily community living with technology has been constantly developing in "young old" population (35). However, the conventional assessment on IADLs, such as the Lawton IADL cannot totally reflect such trends.

In aging theory, capabilities and limitations of people change across their lifespan. There are general patterns of physical and cognitive changes that occur with age. However, the decline of cognitive functions may not be easily noticeable until later stages of neuro-cognitive disorders. This study evaluated individuals aged 65–80 of their abilities with cognitive functions in performing contemporary IADLs and illustrated the importance of both cognitive functions and physical functions in the execution of IADLs for older adults. The selected age range effectively represented the majority of the older people in Hong Kong. Specifically, the minimum bound was set at 65 years of age as it is currently regarded as the defining age of the older people in Hong Kong (36), which is also the minimum age of acceptance into either HE or C&A for those in need (37). It is also the age at which general incidence of dementia occur, which is known to have a significant association with decline in functional status (38, 39). On the other hand, the upper limit of 80 years old was set in accordance with the general life expectancies in Hong Kong, which were 82.2 years for male and 88.1 years for female as of 2019 (40). In ensuring that the recruited subjects were well-suited for the purpose of this study, prospective candidates who were chronic substance abusers or who had major neurological dysfunctions were excluded from our selection, since their cognitive functions and abilities in performing IADLs may significantly deviate from the norm and subsequently lead to unjustified results. In particular, chronic abusers, especially those diagnosed with substance use disorders, are characterized by their inabilities to meet personal or occupational obligations, and they may also withdraw from social activities or even cause ongoing legal problems, such as thievery as a consequence of their drug use. All of these would compromise their abilities in engaging within the community in an orderly manner as well as affect their abilities in performing certain IADLs properly. Therefore, they had all been excluded from participating in this study.

To develop the AIADL scale and establish it as a new measure of older adults' IADL abilities in the digital age of today, we have

TABLE 5 | Classification results of grouping [with $N = 300$; with home living (HL): $n = 100$, hostel for older people (HE): $n = 100$, care and attention home (C&A): $n = 100$].

			Predicted group membership*		C&A	
		Institution	HL	HE		*n*
Original	Count	HL	92	6	2	100
		HE	10	88	2	100
		C&A	1	4	95	100
	%	HL	92.0%	6.0%	2.0%	100%
		HE	10.0%	88.0%	100.0	100%
		C&A	1.0%	4.0%	95.0%	100%

91.67% [Concordant pairs = (92 + 88 + 95)/300] of original grouped cases correctly classified.

**In cross validation, each case is classified by the functions derived from all cases other than that case.*

first recruited experts with over 20 years of clinical experiences to help assess the content validity and cultural relevance of each of the items on the IADL-CV. As the IADL-CV was validated back in 2002, the rich clinical experiences gained by these experts in the past 20 years where they had adopted it as a means of functional ability assessment would ensure that they are the best qualified professionals to provide an expert opinion on the validity of its individual items, and are therefore sufficiently capable of evaluating and scrutinizing the choice of items on the AIADL scale. Furthermore, being practitioners themselves, these experts are well-adapted to the evolvement and utilization of new technologies within the healthcare settings. This has enabled them to develop a keen sense of identifying the types of technologies that are particularly accessible to the older people in their everyday living, which is a highly desirable skill that was constantly employed in the process of devising the AIADL scale. Having established agreement among panel members in finalizing the AIADL scale, which consisted of 10 items with each attaining a kappa score in the range of 0.62–0.75, as well as validating its content validity to be used within the context of Hong Kong, the AIADL scale was further tested for its reliability and validity by our recruited participants. The AIADL scale showed comparable standards of disability and cognitive measures to other well-cited literature (41, 42), and over-weighting the conventional IADL measure (41, 43). Our findings echoed previous literature which documented that IADLs demand performance in cognitive domains, such as memory, attention, and executive function (44).

To maintain coherence with the research design of the IADL-CV (16), HE participants were recruited in the current study. Moreover, the present validation study of the AIADL scale transcended the IADL-CV by recruiting a significantly larger group of participants and wider population spectrum (total participant population = 300) that can provide a more laudable evidence in aging research. The coverage of participants nearly encompassed the main groups of older adults in our community. Taking into consideration this wide spectrum of coverage, the capability to use mobile technology in handling communication and finance was considered as an important ability that is much needed by the older adults for them to live independently in the community (41).

In respect of test-retest reliability, using data from the HL group who had been asked to complete the AIADL scale at two different time points separated by a week apart, the AIADL was found to have reached good test-retest reliability with an ICC of 0.88, and good to excellent internal consistency with a Cronbach's alpha of 0.94. These results were comparable to those presented by Tong and Man (16) in their validation study of the IADL-CV, which had an ICC of 0.90 and a Cronbach's alpha of 0.86. Our results on reliability and internal consistency of the AIADL scale were well above the standard that (45) had stated.

Similar to the findings of Tong and Man (16) on the IADL-CV, using the known-groups method, a high accuracy of prediction on the residencies of older adults within the community was found when the AIADL scale was adopted. Specifically, the AIADL scale had correctly predicted participants from the HL, HE, and C&A groups into their corresponding residencies 92.0, 88.0, and 95.0% of the times, respectively, reaching an overall accuracy rate of 91.67%. In contrast, although the IADL-CV had a high accuracy of prediction rate for the HE group (94%), the overall accuracy of prediction was not as high (78%).

The scale can differentiate between seniors of differing needs and abilities. This study documented and justified that participants living in different residency types would show different patterns of scoring on the AIADL scale. It is reasonable to believe that participants in the HE and C&A groups should maintain communication with their relatives and friends or even for the purpose of handling emergencies *via* ICT and smartphone application. The present study would help the authors in their future work by identifying tasks and activities that differ among various living contexts. Inability of individuals in performing certain IADLs can be referred to occupational therapists so that they could provide further remediation training and compensatory intervention to them. This can further enhance the capability of individuals to cope with aging in place. Moreover, it is interesting to note the discordant pairs $(10 + 1 + 6 + 4 + 2 + 2)/300 = 8.33\%$ as shown in **Table 5**. Ten people who had been classified as HE were predicted as HL. This can be partially explained by the fact that the functional levels of older adults in the HE group were similar to the HL group, except that HE required social support.

Measuring inability of an individual to perform IADLs is important not just in determining the level of assistance required, but as a metric for a variety of services and programs related to caring for the older adults and for those with disabilities. Many Chinese older adults wish to remain living in the

community they have occupied for decades, while others have already downsized or moved into institutional care facilities. The validated AIADL scale helps rehabilitation practitioners assess ability of individuals to successfully manage their IADLs in the contemporary community, a key element that supports the current age-in-place plans. To achieve the goal of aging-in-place, it is necessary to plan for the future and be prepared to respond to changes that come with aging. The validated AIADL scale will serve as a useful reference tool to help identify important areas that are of priority for the future planning of our aging populations. Occupational therapists can also assist with the planning process by making recommendations to maximize independence and helping individuals overcome any areas of difficulty. Recommendations may relate to the care plan of individuals, the use of assistive devices, suggesting activities adaptation, or linking to community support services and programs.

STUDY LIMITATION

The limitations of the AIADL scale assessment include the fact that it is based on the self-report method of administration rather than the performance of functional tasks. This may lead to either overestimation or under-estimation of older adults' abilities (46). It is worthy that further study on how AIADL compare with other IADL tools. Moreover, the lack of comparisons for measuring the efficacy of using ICT devices objectively limits the generalizability of the study findings. Furthermore, in the test-retest reliability assessment, the 1-week test-retest interval could be lengthened to 3 weeks to alleviate the memory and learning effect. Further studies can address this gap to further enhance the quality of the AIADL scale's assessment.

CONCLUSION

The ability in applying ICT is crucial to functional independence and effective aging-in-place of older peoples. Their adoption and handling of ICT should be a crucial parameter to be addressed. It is believed that proper assessment is the corner stone for the future development of telemedicine in our aging population. Healthcare practitioners should also be sensitive to the changing environment, as well as the cultural and social factors around our aging population over time. The two-factor structure of the AIADL scale assessment, "home living and management" and "community living," is shown to be a valid and reliable instrument that can be used to assess the IADL abilities of older adults in this contemporary community.

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

The studies involving human participants were reviewed and approved by The Hong Kong Polytechnic University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

FL coordinated the whole study, developed the research idea, executed the research plan, and monitored the progress. FL, CL, and DM had substantially contributed to the conception and design of the work and analysis and interpretation of research data. AT and AF had conducted the literature review. KY and FL assisted in data collection and including the arrangement for interventions for participants. AT and KY assisted in the literature search and served as the blinded assessors in the study. SW had helped in the earlier drafts of the manuscript and assisted in subsequent revision of the text. They have thus had contributed significant to the article's intellectual content. All authors have agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. 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/fneur.2022.746640/full#supplementary-material

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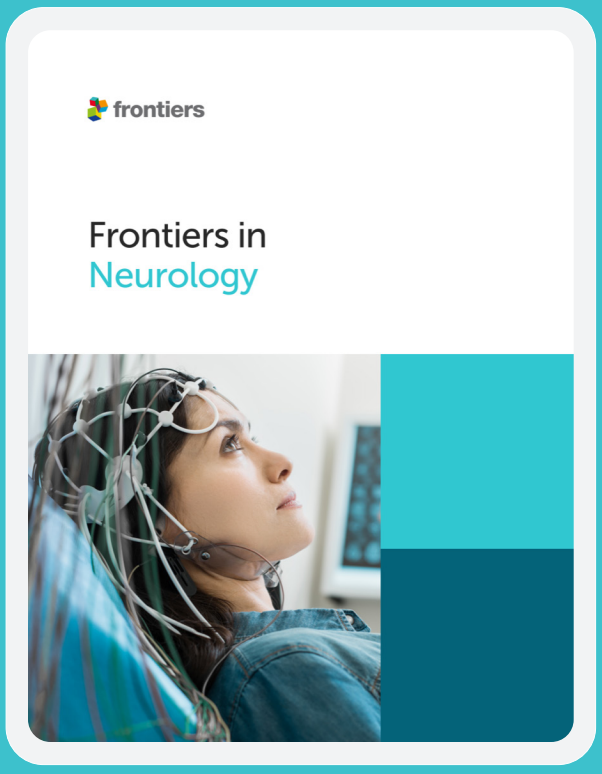

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