

Collaborative Augmented Reality for Older Adults and Family/Close Friends: Protocol for a Feasibility and Acceptability Study

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Abstract

Background: Loneliness and social isolation are common in older adults and can result in increased risk of mortality, cognitive and physical decline, and reduced quality of life. Studies using interactive communication technology (ICT) interventions with older adults have been limited and with mixed results, highlighting the need to design and evaluate ICT to address loneliness in older adults. Advancements in collaborative head-mounted display augmented reality (HMD-AR) can provide older adults who are geographically distant from their families a more diverse range of interactive activities, thus having greater potential to enhance social connection and decrease loneliness.

Objective: The aim of this pilot study was to examine the feasibility and acceptability of co-created collaborative HMD-AR activities and determine study procedures for a future RCT comparing HMD-AR with photorealistic avatars versus 2D ICT (e.g., Zoom) on loneliness among older adults and their family member/close friend.

Methods: Twelve older adults and their designated family/friend were recruited from the greater Nashville area and randomized 1:1 to the HMD-AR or 2D ICT groups. Older adults eligibility: 60 years or older, able to tolerate the HMD-AR, cognitively and physically able to participate, and had an adult family member/friend willing to participate. For long-term care settings, participants must have been a resident for at least 3 months. All participants lived within one hour driving distance from the investigators' university. Each older adult-family/friend pair participated in eight 30-minute sessions over four weeks. Those randomized to HMD-AR had photorealistic avatars created; they participated in collaborative activities (fireplace decoration, checker) co-created in an earlier study. Those randomized to the 2D ICT had the opportunity to play virtual games that are readily available (virtual checkers, house décor game). Engineers remained onsite for both arms to assist as needed. The primary outcome was feasibility of the study processes (i.e., recruitment, retention, data collection) and of the technology (i.e., viability of HMD-AR in home/LTC setting, usability, comfort, ease of use, and acceptability). The study used face-to-face questionnaires and observation.

Results: The study was reviewed and funded by the National Institute on Aging. The study was approved by the local institutional review board and registered at ClinicalTrials.gov. Recruitment for the pilot RCT study began in May 2023 and was completed in April 2025. Final acquisition of data has occurred and currently undergoing data cleaning. Results are intended to be published within one year.

Conclusions: To our knowledge, this is the first collaborative AR using photorealistic avatars between older adults and their family member/friend. Our study will determine if the use of HMD-AR is feasible, and the results of this pilot study will inform a full-scale RCT focused on the efficacy of the intervention with the goal of reducing loneliness among older adults. Clinical Trial: ClinicalTrials.gov NCT06179225

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Original Manuscript

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Collaborative Augmented Reality for Older Adults and Family/Close Friends: Protocol for a Feasibility and Acceptability Study

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ABSTRACT (450 words max, currently 450)**Background.**

Loneliness and social isolation are common in older adults and can result in increased risk of mortality, cognitive and physical decline, and reduced quality of life. Studies using interactive communication technology (ICT) interventions with older adults have been limited and with mixed results, highlighting the need to design and evaluate ICT to address loneliness in older adults. Advancements in collaborative head-mounted display augmented reality (HMD-AR) can provide older adults who are geographically distant from their families a more diverse range of interactive activities, thus having greater potential to enhance social connection and decrease loneliness.

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Methods

Twelve older adults and their designated family/friend were recruited from the greater Nashville area and randomized 1:1 to the HMD-AR or 2D ICT groups. Older adults eligibility: 60 years or older, able to tolerate the HMD-AR, cognitively and physically able to participate, and had an adult family member/friend willing to participate. For long-term care settings, participants must have been a resident for at least 3 months. All participants lived within one hour driving distance from the investigators' university. Each older adult-family/friend pair participated in eight 30-minute sessions over four weeks. Those randomized to HMD-AR had photorealistic avatars created; they participated in collaborative activities (fireplace decoration, checker) co-created in an earlier study. Those randomized to the 2D ICT had the opportunity to play virtual games that are readily available (virtual

checkers, house décor game). Engineers remained onsite for both arms to assist as needed. The primary outcome was feasibility of the study processes (i.e., recruitment, retention, data collection) and of the technology (i.e., viability of HMD-AR in home/LTC setting, usability, comfort, ease of use, and acceptability). The study used face-to-face questionnaires and observation.

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To our knowledge, this is the first collaborative AR using photorealistic avatars between older adults and their family member/friend. Our study will determine if the use of HMD-AR is feasible, and the results of this pilot study will inform a full-scale RCT focused on the efficacy of the intervention with the goal of reducing loneliness among older adults.

Trial Registration: ClinicalTrials.gov NCT06179225

Key Words: Older adults, loneliness, photorealistic avatars, interactive communication technology

INTRODUCTION

Loneliness and social isolation are common health problems among older adults.

Social connection is a critical health determinant in preventing loneliness (the subjective feeling of being alone or isolated) and social isolation (the objective measure of social contact, communication, or social activities), both common health problems among older adults [1-4]. Among community dwelling older adults, up to one-fourth experience social isolation and up to 46% report feeling lonely [2-4]. Among older adults residing in long term care facilities, such as assisted living, social isolation occurs in 4%, moderate loneliness in 61%, and severe loneliness in 35% [5-8]. Social isolation and loneliness have significant adverse consequences: increased mortality, cardiovascular disease, depression, suicide, cognitive and physical decline, reduced quality of life, and increased healthcare utilization [4, 9-11]. A number of recommendations have been made to ameliorate social isolation and loneliness among older adults that include technology-based solutions [3,4,12].

Social Presence as the underlying mechanism in effective interactive communication technology (ICT).

ICT interventions, such as social media and video-mediated visits, have recently been examined for their effects on social connection, social isolation, and/or loneliness among older adults [4, 13–19]. Results have been mixed and the varying designs, ICT mediums, settings, communication partner (family, friend, volunteer, group), measures, and outcomes make it difficult to draw firm conclusions. One potential explanation for the mixed results on social connection is lack of attention to social presence within the ICT. In a recent systematic review of interactive technology interventions with older adults, few studies had a theoretical basis and none examined social presence [19]. Social presence theory refers to the ICT quality and the participant's perceptions, behaviors, or attitudes that other people are physically present [20-22]. Satisfaction with ICTs is based largely on the quality of the social presence afforded. With its foundation in theories of

interpersonal communication and symbolic interactionism, social presence is strongly correlated with the awareness of others and with a sense of connection with others [23]. Social presence is a transient state that varies with the ICT, knowledge of the other person, content, environment, and context [21,23,24].

What is augmented reality (AR) and why use with older adults?

Augmented reality (AR) superimposes digital elements onto the real world that allows real-time interaction between the user and the digital elements; unlike virtual reality (VR) that immerses the person into a synthetic environment, AR allows the user to maintain visualization of their physical environment [25]. AR terminology and type varies [26-28]; our focus is on AR with head mounted displays (HMD-AR) that project virtual content onto some portion of the real world, also referred to as mixed reality [29,30]. Advantages of HMD-AR over HMD-VR are a) it overlays synthetic elements to the real world, thus allowing the user to move about safely because room obstacles are apparent; b) less resource intensive since only virtual objects need to be created and overlaid on a room setting, c) provides greater depth perception, ability to see one's own body, the interacting person's body, and objects resulting in faster task completion times, and d) has fewer side effects: less motion sickness, digital eye strain, or isolation effects [30-35]. Importantly, older adults accept HMDs [35,36]. With the increased computing power of newer AR-based HMD devices, AR is seen as a viable alternative for developing interaction-based interventions for older adults, primarily due to its increased immersion and social presence [22]. The latest AR HMDs have increased field of vision (FOV), seamless hand and eye tracking, robust workspace localization and importantly, users are able to wear the HMD with their glasses on, an important requirement when dealing with older adults.

Augmented reality studies involving older adults

HMD-AR technology has matured but research into its applications for adults 65 years and older is in early stages. Study designs are primarily non-experimental, consisting of small sample sizes, focused on technology hardware and/or software development, and limited activities: park design [37]; exercise, balance training and fall prevention [38-40]; cognitive training and e-learning [27,40,41]. One study used ‘augmented virtual reality’ (a spectrum combining AR and VR elements) to examine a joint meal among three older adults [42]. Few studies have involved older adults with cognitive impairment [41]. All these early studies reveal the promise for HMD-AR: most older adults accepted the technology and experienced few side effects. Suggestions for improvement included: HMD type (lighter weight and fit over eyeglasses); avatar design to be more realistic; increase size of synthetic objects; enhance training for use; and incorporate varying levels of difficulty.

Preliminary Work

Older and younger adults’ perceptions of AR photorealistic avatars as a viable medium for interpersonal communication

Given that AR as an ICT has been understudied, we examined perceptions of older adults (n=31) and younger adults (n=31) utilizing HMD-AR with photorealistic avatars as a format for social communication [43]. In addition, we examined the extent to which photorealistic avatars could portray six common emotions as compared to video clips of the real person. To assess participants’ perceptions, older (n=31) and younger (n=31) adults interacted with a volunteer’s 3D photorealistic avatar using a structured conversational activity through a head mounted display (HMD). Participants rated the quality of the HMD-AR communication based on physical and human realism, comfort while talking to the avatar, and degree of social presence offered by the HMD-AR. Participants then identified 6 basic emotions exhibited by a) video clips of a real person and b) animation of their 3D photorealistic avatars via a head mounted display. Each participant viewed a total of 36 video and avatar stimuli. Subgroup analyses were conducted by age group. Participants reported a positive communication experience with the 3D photorealistic avatar with older adults rating the

quality higher. Ratings were generally lowest for how life-like the model appeared (68% younger adults; 61% older adults). Most were able to accurately identify emotions displayed by the 3D photorealistic avatars although younger adults outperformed older adults (93% accuracy versus 80% accuracy).

Co-creation of collaborative HMD-AR activities

Given the range of physical and cognitive impairments among older adults, especially for those who reside in long term care (LTC) settings, we utilized an iterative participatory design (IPD) methodology involving LTC older adults (n=8), staff (n=5) and family members (n=2) to develop collaborative HMD-AR activities [44]. Several factors were considered: older adults' ability to tolerate HMD-AR for up to 30 minutes without experiencing adverse effects, preferences for HMD-AR activities, and ability to navigate the HMD-AR environment and manipulate AR objects. All IPD activities took place at an LTC in sequential visits over 6 months. At each visit, participants interacted with the HMD-AR activities and provided feedback that was used to refine the specific modes of interaction, game/activity logic, and user interface elements. We found the need to tailor AR activities for these older adults who experienced a range of physical limitations, including impaired fine motor control (e.g., grasping; pinching), cognitive limitations (reduced ability to verbalize thoughts), and sensory impairments (difficulty seeing or reading text). A number of modifications enabled easier interaction for the older adults. Two collaborative HMD-AR activities were developed for the pilot RCT: decoration of a fireplace and checkers.

Specific Aims

The primary aim of this pilot study was to examine the feasibility and acceptability of co-created collaborative HMD-AR activities using photorealistic avatars and to evaluate study procedures for a future RCT comparing HMD-AR with photorealistic avatars versus 2D ICT (e.g., Zoom) on loneliness among older adults and their family member. The secondary aim was to explore facilitators and barriers of HMD-AR implementation using observations and one-on-one interviews

to determine HMD-AR aspects (context, operational, and scalable procedures) and explore individual characteristics that facilitate adoption and usability by older adults.

METHODS

Study design

This was a Stage I pilot study using a nonblinded 2-arm RCT to compare HMD-AR versus 2D ICT among older adults with and without cognitive impairment, residing at home in the community or in a LTC setting (Figure 1).



Participants were recruited from April 2024 through May 2025. The primary aim was to examine feasibility and acceptability of the two interactive communication technologies. We enrolled 12 older

adults and their designated family/friend. After completing baseline assessments, two to four dyads were enrolled at a time because of logistical constraints. Randomization was 1:1. The intervention consisted of 8 sessions over 4 weeks (2 sessions/week). Baseline evaluations were conducted at Week 0. Social presence was evaluated after the second and eighth session. Feasibility and acceptability were evaluated at completion of the study. We also explored facilitators and barriers to AR implementation from the perspectives of older adults and family members.

Study design rationale

We targeted older adults (with and without cognitive impairment) who resided at home or in LTC site given the high prevalence of loneliness or social isolation, resulting in further cognitive and physical decline [4-7]. Reviews have yielded mixed findings on whether men or women are more likely to report loneliness [4,6,45]. Age does not appear to have a relationship with level of social presence in ICT, but women tend to report higher levels of social presence when using ICT [24]. Thus, we will include biological sex and age as covariates in all analyses. We used 2D audio-visual as the comparator since it has become extensively used since the COVID pandemic. It provides audio and visual communication, but limits the quality of the interaction and has had mixed results among older adults residing in the community [4,13-15,46,47]. Our focus is on known family members/close friends because of older adults' desire to maintain meaningful long-term relationships [48]. We examined feasibility and acceptability given these are highly salient for adoption and success [49,50]. An RCT design was chosen for its robustness in conducting future intervention studies. We chose 2 visits per week for 4 weeks duration to allow sufficient exposure to assess feasibility and acceptability. There are a number of HMD products; at the time of this study, we chose Microsoft HoloLens2 given its robustness, wide spread use (e.g., U.S. Army with >80,000 hours of soldier feedback [51], older adult use [52], and ability to fit over eyeglasses.

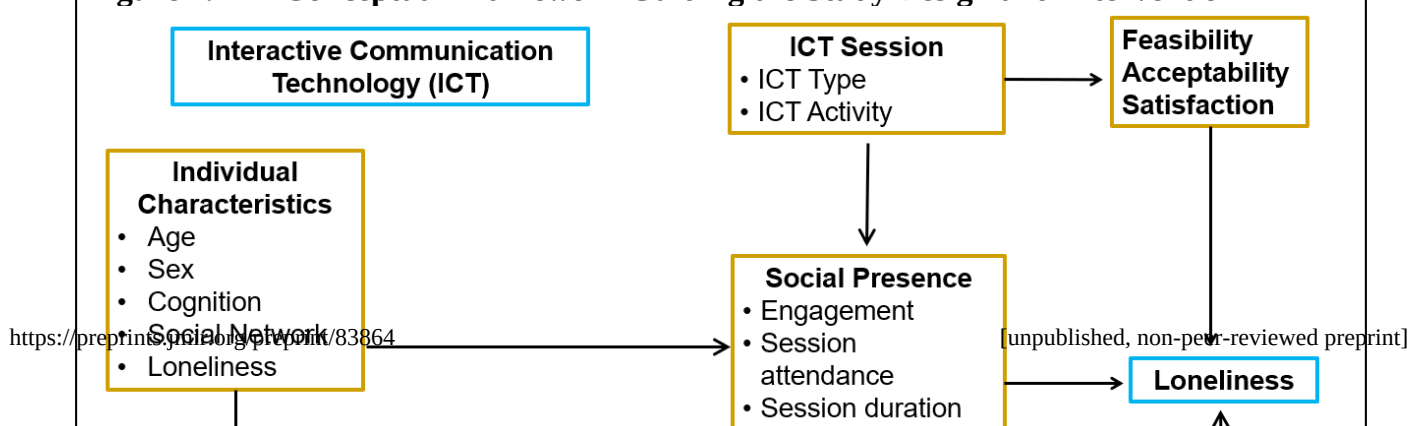
Ethical considerations

The study protocol was approved by the Vanderbilt University Medical Center Institutional Review Board (IRB) (#221150). Written informed consent was obtained in person from all participants prior to data collection and study procedures. To ensure potential participants understood the study purpose, risks, and benefits, we used the University of San Diego Brief Protection of Human Subjects Capacity to Consent instrument [53]. Research assistants (RAs) underwent training to recognize signs of frustration, anxiety, or stress displayed by participants; any sign of discomfort resulted in termination of the session. RAs were trained in procedures to protect privacy and confidentiality. Participants were assigned unique study identification numbers and all de-identified data were stored in a secured database and password-protected. Participants received financial compensation for study activities, including the interactive sessions and data collection procedures, to acknowledge their time and reduce attrition. An external safety officer, designated by the National Institute on Aging (NIA), reviewed and approved the study protocol and informed consent documents prior to start of the study. Bi-annual reports were provided to both the safety officer and the NIA program officer to review progress and any untoward events.

Conceptual framework

Several frameworks guided the study (Figure 2). First, social presence theory postulates the ICT property and the persons' perceptions, behaviors or attitudes that other people are physically present in the ICT affect the quality of the interaction [20,21,23]. We compared two ICTs, HMD-AR and 2D audio-video visits. Second, we used Cohen-Mansfield's engagement framework [54-56] since social

Figure 2. Conceptual Framework Guiding the Study Design and Intervention



in connection framework guided our focus on functional and qualitative aspects of the ICT visits [1]. Last, we adapted the Unified Theory of Acceptance and Use Technology framework [57] to guide evaluation of users' acceptance and use of the ICTs. Individual characteristics of age, sex, cognition, family/friend relationship and social network can impact acceptance and use of ICT [57], type and quality of engagement [58], and loneliness - our future condition of interest [4].

Participants and setting

The study took place in the greater Nashville, TN area. **Older Adults:** Eligibility criteria included older adults aged 60 years and older living within one hour's drive from the principal investigator's (PI) office. If the older adult resided in LTC, they must have been a resident for three or more months. Exclusion criteria were severe cognitive, sensory, or physical impairments that impeded participation; major psychiatric disorder; unable to provide assent; unable to understand or speak English; and acute illness or terminally ill. **Family Members/Close Friend:** Older adults recruited one family member or close friend. Family members/close friend had to be 18 years or older and willing to participate in the HMD-AR and 2D visits and study procedures. For both older adults and family/friends, adequate internet bandwidth was necessary. Eligible older adult-family/friend dyads were randomized 1:1 to ICT type using a computer-generated randomization scheme after baseline measures were completed.

Recruitment

Using IRB-approved communication script, flyers were posted in public areas including the VU parking garages, local community and senior centers, churches and libraries. RAs provided several in-person demonstrations at local centers. E-mails were sent to several assisted living facilities located near VU. Interested older adults and/or family members contacted the investigator team

directly. RAs followed the IRB-approved informed consent document to explain the study either in person or by telephone. A standardized screening checklist was completed to ensure eligibility.

Sample size

There is no precise sample size for early-stage proof of concept technology feasibility study. Nielsen and Landauer found that five users uncovered 85% of usability problems with the technology [59]. Our sample size of 24 participants conformed to the recommended sample size rules of 20-30 for pilot studies as there are diminishing returns for precision with larger sizes and more than sufficient to uncover usability issues [60,61].

HMD-AR and 2D Audio video interventions

For both interventions, the bandwidth within the older adults' and family members' homes was measured and a hotspot used when necessary to facilitate data streaming. A minimum download speed of 80 Mbps was required for data communication. For each session, a trained RA engineer was physically present in both the older adult's and family member's homes to troubleshoot for technological issues during the sessions. The RA trained the participants in establishing ICT (HMD-AR or 2D audio-visual) connection and assisted participants as needed. The RA remained within the room to monitor for technological issues and maintain field notes. Session duration was at the discretion of the older adult and family member, but no longer than 60 minutes.

HMD-AR intervention

Creation of photorealistic avatars

We created photorealistic avatars for all participants randomized to the AR study arm. A mobile app, Polycam, was used to take multiple photos of the participant's face using a 360 view. Polycam constructed a 3D model out of these photos that were then used to create a Metahuman on Unreal Engine matching the facial geometry and the facial features of the participant. However, Metahuman

Creator is limited in its ability to match the features exactly so the RAs added manual touch-ups to ensure the avatar looked similar to the participant. After creating a first version of the avatar, a video call was arranged with the participants to share their avatar with them and get feedback. Participants were able to pick their clothing, hair, body shape, accessories and apply make-up. If a participant was not satisfied with the likeness of their avatar, the process was repeated and more manual touch-ups added. A second meeting was arranged with the participants to share the new version. For most participants, it took one meeting to finalize their avatars.

Experimental setup

Participants in consultation with the RAs determined the physical space for conducting the sessions. General criteria for physical space were that it was free from clutter/furniture/objects to allow for clear overlays of virtual objects and photorealistic avatars and in an area of low traffic to minimize session interruptions. For each participant, equipment included one Kinect camera, a microphone, one head mounted display, and a laptop on which the data sharing and the activity ran and remotely displayed on each participant's HMD. Alienware with a 3060 GPU was used due to the high performance demand of the AR activity. The RAs ensured that both older adult and family/friend were connected before moving to an unobtrusive viewing area. Upon completion of the session, the RA dismantled all equipment and cleaned the HMD-AR with disinfectant wipes.

Collaborative AR activity sessions

Prior to the start of the experimental sessions, RAs provided 1:1 training and orientation to the HMD-AR to ensure the participants were able to navigate the system. In addition, a hard-copy one-page quick reference guide was provided to each participant. Each older adult-family member dyad participated in two sessions a week for 4 weeks (total 8 sessions). Two collaborative AR activities were available to the participants [see 44 for details]: fireplace decoration and/or checkers. If the fireplace activity was selected, participants could choose from a variety of virtual objects to decorate

the fireplace mantel, hearth, or nearby wall. For the checkers activity, each participant sat at a table and the checkerboard and checkers appeared as a virtual object on the space. Participants were able to see each other's photorealistic avatar with both activities. Upon completion of each session, the participants would let the RAs know who turned off the AR display and stopped the data communication.

2D Audio video intervention

Experimental setup

Participants in consultation with the RAs determined the physical space for conducting the sessions, preferably in an area of low traffic to minimize session interruptions. If the participants were placed in the 2D ICT group, they could use their personal computer. In the event the participants did not own a device, a laptop was provided at each session. The RAs ensured that both older adult and family/friend were connected before moving to an unobtrusive viewing area. Upon completion of the session, the RAs recovered any loaned devices.

Collaborative 2D Audio Video Sessions

For the study, we used Zoom videoconferencing application for all sessions. Prior to the start of the experimental sessions, RAs provided 1:1 training and orientation to using the laptop device if needed, especially for older adults unaccustomed to tablets/computers, and to logging in to Zoom. Participants were provided links to an online checkers game and an online room decoration activity that they could engage in during the session. A one-page quick reference guide was provided to each participant.

Ensuring intervention fidelity

We incorporated recommendations from the National Institutes of Health Behavior Change Consortium to maximize treatment fidelity across the RAs and over time [62]. In brief, we used

Data collection procedures

Table 1. Study Assessments and Schedule of Evaluations

[illegible]

Assessment	Enrollment & Baseline	Week 1 Sessions 1 & 2	Week 2 Sessions 3 & 4	Week 3 Sessions 5 & 6	Week 4 Sessions 7 & 8	Week 6 Follow- up: Final Visit
-6-item UCLA Loneliness Scale						
Session Variables Attendance Engagement- Observational Measurement of Engagement Tool 3-item UCLA Loneliness Scale 6-item Mutual Awareness Subscale (social presence)		X	X	X	X	
Outcomes Feasibility & acceptability - FIM Questionnaire - AIM Questionnaire Network Minds Measure Inventory (social presence) -6-item UCLA Loneliness Scale -Semi-structured interviews of facilitators and barriers						X

^aLimited to those residing in assisted living facilities.

^bOnly for older adults. SAGE = Self-Assessment Gerocognitive Exam

^cFor those residing in assisted living facilities, utilized the Lubben Social Network Scale for Long Term Care Settings.

Measures

Feasibility and acceptability outcomes

Feasibility, defined as the practicality of conducting the study [64], was measured by observation and documentation of recruitment and retention rates, data completion, and session attendance (i.e., intervention completion). Logistic, technological and user issues were observed and documented

after each session. We measured intervention implementation rates for both arms of the study as the proportion of successful connections. Feasibility was also measured by the participants' perceptions of the ease in using the technology using a valid and reliable four-item questionnaire, Feasibility Intervention Measure (FIM) [49]. Each item was rated on 5-point Likert response ranging from 1 (completely disagree) to 5 (completely agree). Data were collected at the final 2 weeks post follow-up visit. Acceptability, the perception that the intervention (HMD-AR or 2D audiovisual) was agreeable and palatable, was measured using a valid and reliable four-item questionnaire, the Acceptability Intervention Measure [49]. Each item was rated on 5-point Likert response ranging from 1 (completely disagree) to 5 (completely agree). Data were collected at the 2 weeks post follow-up visit. Overall satisfaction with the ICT was ascertained at the final session via semi-structured interviews.

Baseline variables

For both older adult and family member participants, baseline data were collected on demographics (age, gender, race), social network, and loneliness. Social network was assessed using the 12-item Lubben Social Network Scale, a self-report measure of social engagement with family and friends [65]. Each item is rated using a 6-point Likert response ranging from 0 (no monthly contact) to 5 (daily contact); scores range from 0 to 60 with higher scores indicating a greater social network. For older adults residing in LTC, the Revised Lubben Social Network Scale – Long-Term Care Scale [66] was used; this scale includes an additional 11 items that assesses quality and frequency of interactions with other residents and staff persons. Loneliness was assessed using the 6-item Revised UCLA Loneliness Scale [67], a self-report measure consisting of 6 items rated using a 4-point Likert response. The score ranges from 6 to 24 with higher scores indicating greater loneliness.

For older adults, cognition was assessed using the Self-Administered Gerocognitive Examination (SAGE) [68,69]. The SAGE is a brief tool that assesses language, reasoning/computation, visuospatial, executive, memory, and orientation. Scores range from 0 to 22 with scores >16

suggesting normal cognition. Physical function was assessed via self-report using the Barthel Index [70]. Participants rate their degree of independence performing 10 activities of daily living (e.g., bathing, dressing); scores range from 0 to 100 with higher scores indicating greater independence.

Interactive communication technology sessions

Immediately after each session, RAs completed a modified Observational Measurement of Engagement [54] instrument to note engagement behaviors, type of activity, level of noise, and lighting. Additional field notes provided contextual information in understanding the older adults' engagement with their family member with each type of ICT. Participants were asked to complete the 3-item UCLA Loneliness Scale [71].

The Mutual Awareness Subscale (MAS) of the Networked Minds Measure of Social Presence [72] was completed after the second and eighth session. The MAS is an 8-item questionnaire that is rated using a 5-point Likert response ranging from 0 (never) to 4 (a great deal); scores range from 0 to 32 with higher scores indicating a greater sense of social presence with one's partner.

At the last session, participants completed the Networked Minds Measure of Social Presence instrument, consisting of several subscales: Mutual Awareness Scale (8 items), Perceived Attentional Engagement (6 items), Perceived Emotional Contagion (8 items), Perceived Comprehension (6 items), and Perceived Behavioral Interdependence (6 items). Higher scores indicated greater social presence. Loneliness is the targeted primary outcome for future studies; thus, participants also completed the 6-item UCLA Loneliness Scale [68]. Last, the RAs conducted a brief interview using a semi-structured questionnaire to elicit participants' perceptions of facilitators and barriers.

Analysis plan

We will produce a Consort flowchart to track the progress through the phases of the trial (enrollment, intervention allocation, follow-up, and data analysis). Reasons for non-eligibility, non-participation,

and attrition will be documented and summarized. Study aims will be analyzed using both quantitative and qualitative analysis. Quantitative data of feasibility and acceptability (e.g., participant recruitment, enrollment and retention rates) will be descriptively analyzed using frequency distributions and measures of central tendency and dispersion as is appropriate. For multi-item scales (e.g., social presence, FIM and AIM), descriptive statistics will be computed for both the scale scores and for individual items. Additionally, we will estimate loneliness at each time point and produce trend plots by intervention groups. We will report both the point and precision estimates (e.g., 95% confidence interval) for all the quantitative estimates. We will also examine the extent of missing data, document and summarize the reasons, and explore pattern of missingness. Qualitative data of feasibility, acceptability, facilitators, and barriers will be analyzed by first transcribing recordings verbatim and using ATLAS.ti software to help manage the interview content and analysis. Analytic conflicts will be resolved by consensus of the investigator team. Validation will be obtained through member checking with the participants.

DISCUSSION

This study will assess the feasibility of implementing HMD-AR communication between older adults and family members/friends and identify key facilitators and barriers to implementation. This project has several innovations. First, collaborative HMD-AR delivers enhanced social connection for older adults and their family members/friends via a 3D hologram using realistic avatars that are transported to each other's environments. Most prior work on older adults in AR focuses only on a single user and does not include collaborative aspects. Second, the proposed technology has the capability to map the remote users' interactions with augmented objects in a chosen environment. Interactions can be mapped efficiently even when the remote and local users' environments are non-isomorphic. Third, assessing the feasibility and acceptability of collaborative AR among older adults residing alone in the community will be new to the literature. We bring to the knowledge on technology interventions targeted to addressing loneliness the underlying mechanism of social

presence in interactive communication technology.

Several limitations exist. It will not be possible to blind participants to study arm. Attrition can significantly impact studies with small sample sizes. Based on our prior experiences, we believe attrition will be low but may occur due to illness or disinterest. We will address attrition by regular communication with the participants and schedule sessions at times convenient to participants. Cost and complexity may be issues in applying advanced ICT. We chose to use commercially available non-proprietary equipment to minimize costs. We will make computational algorithms freely available. AR technologies and components are becoming cheaper as the demands and applications increase. Almost any new technological intervention plan will introduce additional cost and complexity both in the home and in the existing system of care; our proposed system will be no exception. Whether such additional burden justifies the new technology is a question that needs to be answered on case-by-case basis.

Our work will expand on earlier studies and focus on HMD-AR to address loneliness. We expect a greater understanding of the feasibility, acceptability and social presence in the use of varying collaborative HMD-AR activities and environments for older adults with different levels of cognitive impairment and their family members. We anticipate greater understanding of the logistics and deployment of this technology in homes and in LTCs.

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Authors' Contributions

Conceptualization: NS, JT, LJ, CAM, DWS, AT, LCM

Methodology: NS, LCM, AT

Software: AU, MT, NS, ZI, RZ

Validation: MT, NS, JT

Formal analysis: AT

Investigation data collection: MT, ZI, RZ

Resources: NS

Data Curation: MT, AT

Writing – Original Draft: LCM, MT

Writing- Review & Edit: NS, JT, LF, CAM, DWS, LCM, MT, RZ, ZI, LAJ

Visualization: MT, LCM, AT

Supervision: NS, JT

Project Administration: NS

Funding Acquisition: NS, LCM

Conflicts of Interest

None declared.

Generative AI: Google AI was used a) to assist in identifying key articles in augmented reality and older adults and b) to generate a title meeting the journal's guidelines.

Abbreviations

2D	Two-dimensional
3D	Three-dimensional
AIM	Acceptability Intervention Measure
AR	Augmented reality
FIM	Feasibility Intervention Measure
FOV	Field of vision
GPU	Graphics Processing Unit
HMD-AR	Head-mounted display augmented reality
ICT	Interactive communication technology
IRB	Institutional Review Board
LTC	Long term care
MAS	Mutual Awareness Scale
NIA	National Institute on Aging
PI	Principal Investigator
RA	Research assistant
RCT	Randomized controlled trial
REDCap	Research Electronic Data Capture
SAGE	Self-Administered Gerocognitive Examination

VR
VU

Virtual reality
Vanderbilt University

Preprint
JMIR Publications

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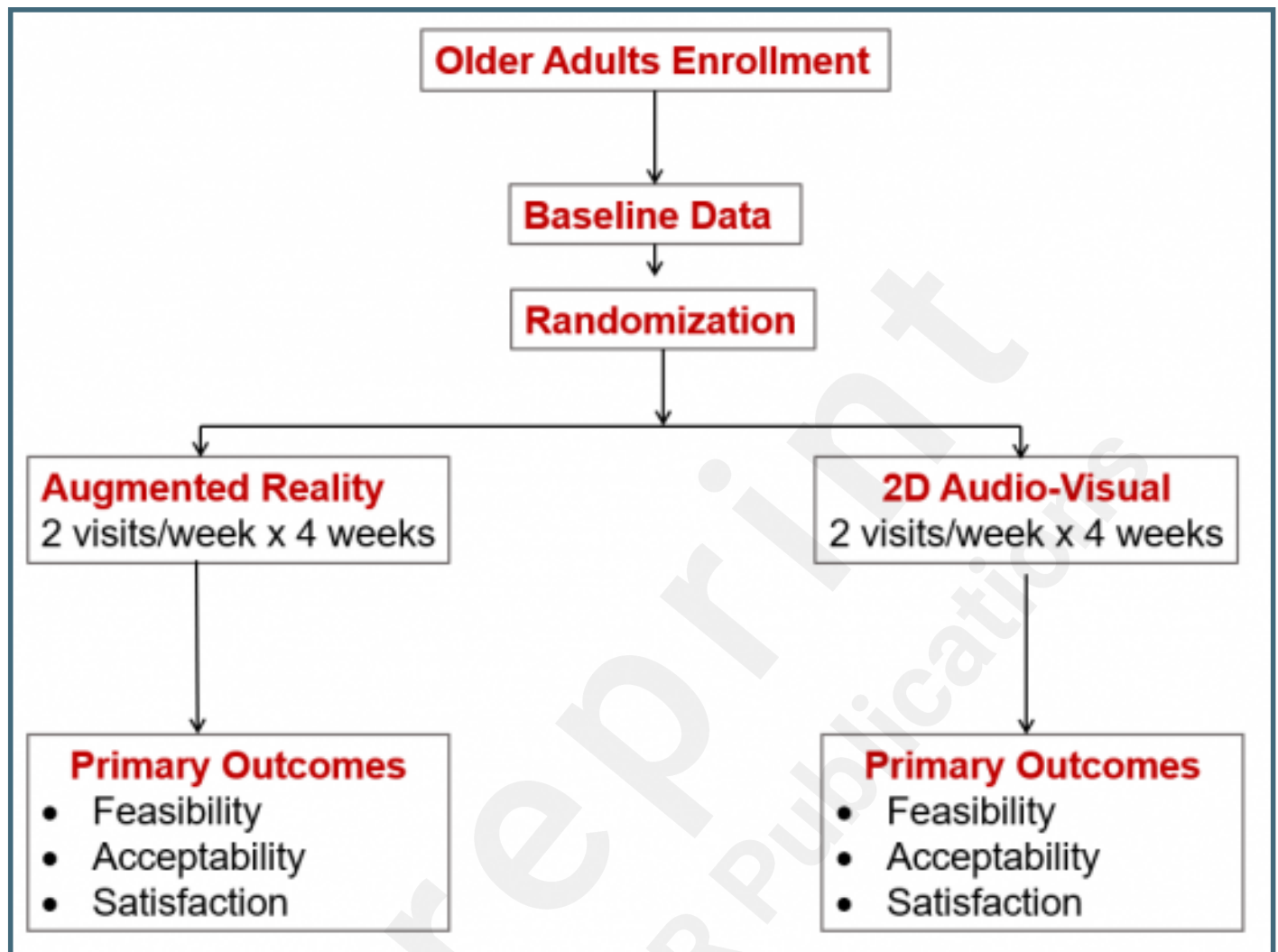
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Supplementary Files

Figures

Study Flow Diagram.



Multimedia Appendixes

R21 summary statement.

URL: <http://asset.jmir.pub/assets/3becda54941dfed5d1bc4f28804e9388.pdf>

Investigator response to summary statement.

URL: <http://asset.jmir.pub/assets/ef5854af3dc065fee0f8694978c097ec.docx>

Table of study measures.

URL: <http://asset.jmir.pub/assets/5964b36410aaf8db50bc5620be279001.docx>



CONSORT (or other) checklists

CONSORT-EHEALTH checklist Sarkar.

URL: <http://asset.jmir.pub/assets/eed7a7208ee162ae17e9d5a70627b009.pdf>