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VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

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VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

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Keywords: Virtual Reality, Dementia, Caregivers, Social Interaction, Quality of Life

ABSTRACT

Introduction: Virtual Reality (VR) technology is increasingly used by researchers and healthcare professionals as therapeutic interventions to improve the quality of life of persons living with dementia (PLwD). However, most VR interventions to date have mainly been explored in long-term or community care settings, with fewer being explored at home. Setting is important given that the majority of PLwD live at home and are cared for by their family care partners. One of the challenges affecting PLwD and care partner relationships is barriers in communication, which can lead to social isolation and poor quality of life for both parties. Thus, the goal of the proposed project is to explore whether an immersive, multisensory VR intervention can facilitate communication between PLwD and their care partners and, in turn, enhance personal relationships and improve well-being.

Methods and analysis: Thirty dyads comprised of individuals with mild-to-moderate dementia and their family/friend care partners will participate in this at-home intervention. Their interactions will be recorded as they watch a series of 360-degree videos together (e.g., concert, travel) either using a VR headset (PLwD) with a paired tablet (care partner) or using only a tablet together. The two conditions will allow us to compare immersive VR-technology to more common non-immersive Tablet-based technology. The study will begin with at-home training and baseline data collection. The intervention will then take place over a 4-week period, with the two conditions (VR vs. Tablet-only) experienced two weeks each. A comprehensive set of measures will be employed to assess the quality and quantity of dyadic interactions, such as verbal/non-verbal language (e.g., informativity, gestures), and self-reported measures of well-being and quality of life.

Ethics and dissemination: Ethical approval for the study was granted by the University Health Network (# 21-5701). Findings will be shared with all stakeholders through peer-reviewed publications and presentations.

Strengths and Limitations of the Study:

- Strengths: The findings will inform both the utilization of VR technology for therapeutic purposes and the future design of VR systems and content for PLwD, particularly for use in a home setting.
- Evaluating a non-pharmacological, at-home intervention could specifically improve interpersonal relationships between PLwD and care partners, which has not yet been fully explored as a key outcome.
- Whereas previous VR studies have evaluated beneficial effects of VR interventions, very few have considered whether immersive VR technologies result in better outcomes than traditional display technologies (e.g., tablets).
- Weaknesses: Participating care partners will comprise of English-speaking individuals living in the greater Toronto region and thus our findings may not be generalizable to the general population.
- To reduce the potential for simulator sickness and disorientation, the selected videos will not include any large-scale movements and consequently, the level of engagement may be less than other interactive VR experiences.

VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

INTRODUCTION

The number of individuals living with dementia is estimated at 50 million people globally and these numbers are expected to rise substantially with the increasing aging population [1,2]. Recent years have seen a significant rise in research exploring the use of head mounted Virtual Reality (VR) systems for persons living with dementia (PLwD) [see 3, for a review]. Some of this work has focused on exposing PLwD to immersive experiences in virtual environments (e.g., experiencing nature, travel, concerts and sporting events) with the goal of eliciting reminiscence and positive affect and improving overall well-being [3–10]. A unique aspect of this type of VRx-therapy is that it allows PLwD to be transported to alternate realities and to have experiences that they may no longer be able to have because of the functional limitations that accompany their symptoms. To date, the evidence suggests that these exposure-based VRx-therapy interventions are feasible and have potential to improve PLwD's mood, well-being, and quality of life [4,8,11,12,12]. However, most of this evidence stems from studies that have taken place in the context of long-term care or community care settings where a researcher or a trained formal care provider administers the VRx-therapy. Relatively less is known about the utilization of VRx-therapy for PLwD in an at-home setting and in the context in which the family/friend care partner administers the intervention. This is an important context to explore as most PLwD live at home and are cared for by their family members, and thus there is great potential for evaluating whether VRx-therapy can be prescribed as a non-pharmacological solution to address the needs of this population.

Over the past several years, members of our team have evaluated a prototype version of the VRx-therapy in several studies including a multi-site pilot feasibility study across several long-term care facilities and ambulatory out-patient clinics, involving 70 individuals with varying severities and types of cognitive and physical impairments [4–6]. Participants experienced 360-degree nature videos while wearing a head mounted VR system. In general, it was found that the intervention was feasible and well-tolerated by participants, who also reported feeling more relaxed after their VRx-therapy exposure sessions. One important, but somewhat unexpected, observation that emerged from this work was that the VR interventions appeared to increase interpersonal engagement of the users. Specifically, residents wanted to share their experiences with their formal care partners (e.g., nurses), visiting family members, and other residents. Other emerging evidence has demonstrated that experiencing realistic scenes and scenarios through VR is an effective strategy for reminiscence therapy in PLwD, leading to increased engagement, improved mood, and greater feelings of well-being [7,8,10,13–15]. However, VR interventions, while momentarily helpful, have also been described as potentially "isolating" in the sense that, in most cases, PLwD are experiencing them on their own. Indeed, the most meaningful real-world experiences are typically those that we share with others, especially our friends and families. Hodge and colleagues [16] recommended that future VR designs focus on "making room for sharing" and suggest that VR experiences may provide a "ticket to talk" (a tool to elicit conversation and increase engagement), which could lead to enhanced PLwD-care partner relationships. To our knowledge, the concept of VR as a "ticket to talk" in this population has not been empirically evaluated, or carefully measured as an outcome of VRx-therapy based interventions. Therefore, in the current study, we aim to use VR as a tool to facilitate communication between PLwD and family/friend care partners at home. This will be achieved by having PLwD and care partners jointly experience the content presented within the virtual environment, which will provide them with an opportunity to converse about their experiences. Specifically, care partners will be given a tablet which will mirror the viewing perspective of the PLwD's VR experience in real time. The shared VR intervention proposed here is expected to be beneficial not only for PLwD but also for care partners– something neither targeted nor measured in previous studies.

Barriers to communication is a key challenge that care partners face at home, and it negatively impacts care partners' relationships with PLwD. Communication barriers have been shown to lead to loneliness, social isolation, and poor quality of life for both PLwD and care partners [17–20]. There is some evidence that communication aids designed to elicit conversations (e.g., tools that present pictures, videos, music), are effective at improving interactions between PLwD and care partners [21,22]. Most of these interventions, however, have focused on other types of technology-based aids such as applications for phones and tablets [21,23] and digital memory books containing generic or personal photographs [24]. One aspect of VR that makes it unique from other display technologies such as televisions, computers, and handheld mobile devices is the level of immersiveness that is achieved. Immersion in VR is related to the extent to which our senses are presented with simulated inputs from the virtual environment [25]. One of the key benefits of VR's immersiveness is that individuals can have new experiences that feel very real in a controlled and safe environment, such as in one's own home.

The proposed project explores whether an immersive, multisensory VR intervention focused on "sharing experiences together" can facilitate communication between PLwD and their care partners and, in turn, enhance interpersonal relationships and improve quality of life. Further, we will explore whether the added level of immersiveness provided through multisensory VR is even more effective at facilitating communication than non-immersive tablet-based technology, which is a more commonly used tool in communication and reminiscence therapies. Although both tools are capable of providing a "shared experience", it is not yet known whether one is more effective than the other in facilitating communication. VR is not only more immersive but also a novel technology that could be considered more fun and engaging by participating families. There are, however, other benefits that are unique to tablet technology such as being more familiar and easier to use. In addition, while using the tablet together, PLwD and care partners can engage in joint attention and exchange more nonverbal behavior (gaze, facial expression), which are integral aspects of everyday interaction that could further facilitate verbal communication.

OBJECTIVES AND PREDICTIONS

The overarching goal of the current study is to design and evaluate a virtual reality at-home intervention to facilitate communication between PLwD and their care partners, and in turn improve their interpersonal relationships and quality of life. In particular, we are interested in examining whether VRx-therapy could help elicit and maintain conversations, increase positive affect, and evoke reminiscence through the sharing of memories. The project also aims to provide a direct comparison of an immersive VR system with non-immersive tablet-based technology.

In addition to collecting self-report measures of communication and well-being, we will introduce a picture book session to capture baseline measures of communication between PLwD and care partners. Comparisons between the VR and Tablet-only conditions will be made relative to these baseline measures. We predict that relative to baseline, both VR and Tablet-only conditions will facilitate communication, as these technologies provide a greater multisensory experience. Specifically, they include extra sensory input through audio, as well as have dynamic scenes that allow for multiple viewing perspectives (similar to real-world experiences). In terms of the VR and Tablet-only comparison, one possible outcome is that the VR condition, which is more immersive, will be more likely to evoke reminiscence, elicit positive affect, and increase presence, which in turn would lead to enhanced verbal (e.g., longer conversations) and non-verbal (e.g., more laughs) communication than the Tablet-only condition. Another possibility is that the Tablet-only condition will be more likely than the VR condition to elicit conversations and reminiscence because the PLwD and care partner can engage more in nonverbal communication (eye-contact, facial expressions). Finally, we anticipate that an increase in communication and reminiscence will in turn have a positive impact on users' well-being and positive perceptions of the experiences with both technologies.

METHODS

Participant, family, and community involvement

We will employ a participatory design method by actively engaging PLwD, family care partners, and community care partners in every stage of our study (from design to implementation to data interpretation). We have also consulted with members of our multidisciplinary team who have expertise in hearing, vision, communication, and technology. These stakeholders have assisted us with the selection, design, and development of the VR content and assessment techniques. After creating the content, we collected preliminary ratings of each video's audio/visual quality, interest, and discomfort/side effects. Recently, we also completed a pilot study with seven PLwD-care partner dyads (5 completed the full study, 2 dropped out due to lack of interest or time) to explore the feasibility of this at-home intervention and to collect feedback on the digital content, study materials and procedures. We have updated the study materials and procedures based on the feedback we received from both PLwD and care partners. One of these changes involved simplifying the study to include fewer interviews and questionnaires, thus reducing the demand on care partners. Other changes were more specific to increasing the types of content that were considered more engaging (for example, increasing the number of videos with singing and dancing). The results of the pilot study are described in separate publications [26].

Participants

Thirty individuals with mild to moderate dementia and thirty care partners (friend or family members of the PLwD) will be recruited to participate in the study. As part of the recruitment plan, printed flyers will be posted throughout the community surrounding the greater Toronto region (e.g., hospitals, local university campuses, community centers, and libraries). Digital flyers will be disseminated via websites, social media, and through our community partners. Efforts will be made to recruit equal samples of male and female PLwD and care partners, allowing for further analyses exploring group level differences and understanding how sex/gender may affect the intervention outcomes. In addition, given that vision and hearing abilities play an important role in our intervention and are known to be particularly prevalent in PLwD, we will specifically collect information on participants' sensory abilities. This will allow us to explore whether the observed outcomes are in any way influenced by sensory abilities.

Eligibility Criteria

Given the nature of the study, the participating dyads will be required to have access to high-speed internet with a reliable WiFi connection. Additional inclusion/exclusion criteria are as follows:

PLwD inclusion criteria:

- report having mild to moderate dementia
- currently living at home

PLwD exclusion criteria:

- recent history of seizure, epilepsy, head trauma, or stroke
- pacemaker
- cervical conditions or injuries
- open face wounds
- alcohol-related dementia/ Korsakoff syndrome
- having a Public Guardian and Trustee as substitute decision maker

Care partner inclusion criteria:

- identify as one of the primary care partners for the PLwD
- able to speak and understands English

Care partner exclusion criteria:

- professional/formal care partners for the PLwD
- unable to provide informed consent

Materials and Apparatus

The study will have one main within-participant experimental manipulation, namely the presentation of different visual media: VR vs. Tablet-only for intervention and standard picture book for baseline.

Picture Book

To capture baseline measures of communication between PLwD and care partners, participants will be presented with a photo album containing high-quality prints representing themes from scenes that will be viewed on the Tablet/VR.

Tablet

PLwD and care partners will view non-immersive 360-degree videos together using a commercially available Samsung Tablet. PLwD will be able to move the position and perspective of the virtual environment using the touch screen (dragging the view around with their finger). All 360-degree videos (described below) will be uploaded to the Tablet and played using the VRx@Home study app, specifically designed for this at-home intervention. The custom app has a simple interface and is accessed by participants via a unique login. This login will enable us to control the selection of videos accessible to participants for each particular week of the intervention, and anonymously track their usage (i.e., by name of the videos selected and length of time watched; see the study website for a demonstration of the app).

VR

PLwD will view immersive VR experiences (360-degree videos) using an Oculus Quest 2 VR system that has built-in, over-ear headphones. The PLwD will be watching dynamic videos from a static position and although they will remain in one location within a scene, they will have the ability to look 360-degrees around and explore through head movements and thus change their perspective in the scene. However, they will not be able to translate or teleport within the scene or move from a stationary, seated position in the real world. This method significantly reduces the chance of feeling motion sickness in VR.

The care partner will be seated nearby to ensure the safety of the PLwD and to jointly experience the virtual content on a paired tablet mirroring the VR display. As such, the care partner will be able to see the content of VR from the exact same perspective as the PLwD but will not be able to manipulate the viewing perspective. In addition, the care partner will use the tablet to select the videos and stop the session if there are any concerns for safety or any signs of distress from the PLwD.

Figure 1. Study Conditions and Materials

Picture Book Tablet VR

Note. Consent for photograph release was provided by the participants

Recording Tools

Video and audio recordings will be captured through a video-conferencing application. We will follow recommended guidelines to set up a secured conference call (via Zoom) on a supplied laptop. If the researchers find it difficult to hear the PLwD during the initial Zoom meeting, then a digital audio recorder will also be provided. In this case, participants will be asked to place the digital recorder closer to the PLwD as a backup device to capture the conversations. All recordings will use anonymized participant IDs. PLwD and care partners will be given a journal and asked to record personal reflections about the sessions to capture any feelings, observations, or opinions about the VR, the Tablet, or the experience in general not otherwise collected by the study tools.

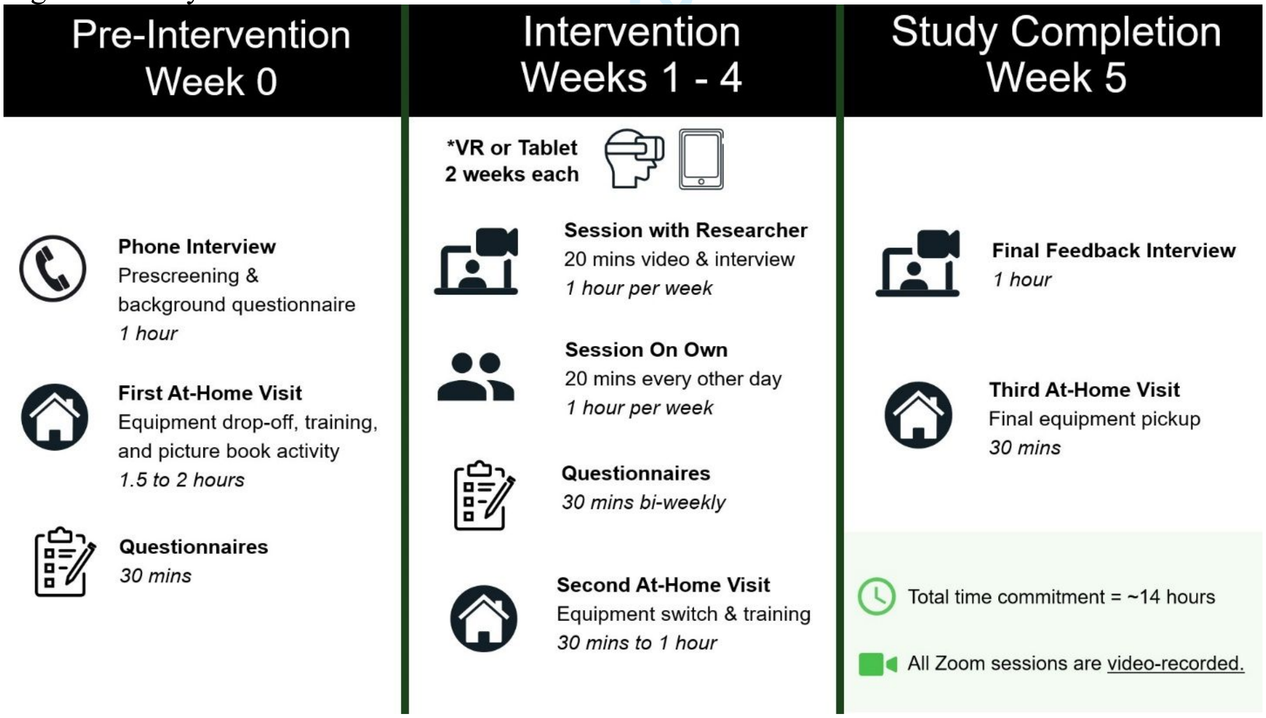
Visual and Auditory Stimuli

We created an extensive library of scenarios (360-degree videos with sound) that are each approximately 5 minutes long (84 videos). These scenarios are broadly categorized into four themes: Entertainment (e.g., ballet, musical concerts), animals (e.g., dogs, giraffes), travel (e.g., Niagara Falls, Paris), and sports (e.g., baseball, gymnastics). Participants will be presented with four of these 5-minute scenarios during their initial weekly exposure sessions (20 minutes total viewing). The pairings of scenarios to condition (VR or the Tablet-only) will be systematically structured. This will ensure that a particular scenario is only presented once to each participant, and thus, will be novel. The particular themes and order of videos will be pre-established in separate lists and participants will be randomly assigned to one of these ordered lists. In addition, participants will have access to a library of at least 21 videos per theme to choose from for their every-other-day experiences (described below).

Study Phases and Procedures

The full study will be approximately 5 weeks long per participant dyad. The intervention phase will be 4-weeks long, with an additional week allocated for pre-screening participants and at-home visits. In total, there will be 3 at-home visits where the researchers will drop off equipment and provide training (week 0), switch devices (VR or Tablet-only condition) and provide additional training, if necessary (week 2), and pick up the equipment (week 5). The rest of the intervention will be conducted fully remotely through online video-conferencing software, online questionnaires, and journaling. See Figure 2 for a summary of the study procedures and timeline.

Figure 2. Study Procedures and Timeline



Note. VR and Tablet-only conditions are experienced for two weeks each, in a counterbalanced order across participants.

Pre-Intervention

After eligibility is confirmed over a pre-screening telephone interview and informed consent is provided, we will schedule the first equipment drop-off and training session conducted in person. During this session, we will provide training on how to use the devices and video-record the study sessions. We will also show participants how to access and complete the questionnaires/surveys through the application on the supplied laptop. The PLwD and care partner will be asked to view the picture book together and record their interactions via the video-conferencing software. The picture book not only serves as our baseline control condition, but it also allows the participants to become familiarized with the video conferencing tool that they will use during sessions with the researcher. In addition, the researchers will test the quality of video and audio during this session and determine whether the backup digital recorder is necessary.

Intervention

The next four weeks will be the intervention phase where participating dyads will either receive a VR device (plus mirrored tablet) or only the Tablet device for two weeks (weeks 1 and 2), and then receive the other device (VR device or Tablet-only) in the following two weeks (weeks 3 and 4). Across the VR/Tablet conditions, participants will be asked to simply watch the videos and explore the content through head movements (VR) and touch screen navigation (Tablet) as desired.

Beginning every week, we will audio and video record PLwD-care partner interactions (verbal and non-verbal language) during the Tablet/VR experience. This weekly exposure session will include 20 minutes of viewing the pre-determined video sequence, followed by a feedback interview conducted by the researcher regarding their experiences and preferences. Participants will then be asked to use the system every other day by choosing from a selection of videos made available to them on the app (17 additional videos per theme in addition to the four videos they will watch with the researcher). They will be asked to continue recording their interactions as they watch these videos on their own (3 times per week x 20 minutes each). Finally, they will be asked to complete online questionnaires regarding communication and measures of well-being after each phase of the intervention (VR vs. Tablet-only).

Study-Completion

On the final week of the study (Week 5), we will conduct a formal interview to evaluate the feasibility and effectiveness of the intervention and collect the equipment.

Outcome Measures

Table 1 provides an overview of all outcome measures and the phase of the protocol during which they will be administered.

Baseline Measures

We will first collect measures on demographics, general health, technology use, and cybersickness susceptibility using questionnaires and semi-structured interviews. Apart from cybersickness (only asked of PLwD), all these measures will be collected from both the PLwD and their care partner.

Primary Measures: Verbal and Non-Verbal Communication

Our primary outcomes of interest are measures of verbal and non-verbal communication captured through audio and video recordings as well as self-reported through questionnaires and journal entries. These data will be collected throughout the intervention and evaluated using standardized scales, thematic analyses, and coding schemes developed specifically for the study. The following characteristics of verbal and non-verbal communication will be measured:

Verbal:

- Quality of conversation and dyadic interactions as assessed through questionnaires:
    - Measure of Participation in Conversation for Dementia (MPC-D) [27]
    - Measure of Support in Conversation for Dementia (MSC-D) [27]
    - Custom communication questionnaire
- Language performance measures:
    - Utterance length (total duration and mean length of utterance)
    - Conversation initiation (count of how many times PLwD initiated conversation)
    - Fluency (amount and type of disfluency)
    - Coherence/Informativity (topic maintenance, off-topic verbosity)
    - Affect in language (sentiment analyses)
- Reminiscence/Storytelling (number and the length of episodic memories)

Non-verbal:

- Facial expressions (frequency of smiles/laughter, frowns/grimaces)
- Gestures (e.g., frequency and type of gestures)

Secondary Measures: Well-Being and Quality of Life

Measures of well-being and quality of life (e.g., relationship quality, mood, mental health), will be assessed through standardized questionnaires (see Table 1). Both PLwD and care partners will complete these measures pre- and post- each phase of the intervention (bi-weekly following each Tablet-only and VR condition). In addition, interviews will be conducted to capture any feelings, observations, or opinions about the VR/Tablet-only experiences, or the study materials/procedures not otherwise captured by the study tools.

Secondary Measures: Preference and Usability

We will use standardized measures, semi-structured interviews, and information provided in the journal to assess participants' opinions of the devices and experiences (e.g., device tolerance/comfort, content preference, challenges and areas for improvement).

Table 1: Summary of all Outcome Measures

Outcome Measure Categories	Instrument and Measurement Tools	Participant Group	Time Point		
			Pre-Intervention	*Intervention (weekly)*	*Post-Intervention (bi-weekly)*
Baseline					
Demographic & Health	Demographic & Health Survey	PLwD* & Care Partner	X		
Technology Use & Comfort	Technology Survey	PLwD* & Care Partner	X		
Cybersickness Susceptibility	VIMSSQ-short[1]	PLwD*	X		
Primary					
Dyadic interactions (e.g., conversation quality, participation, support, & engagement)	-MPC-D & MSC-D -Communication Survey	PLwD & Care Partner	X	X	
Verbal Communication (e.g., utterance length, coherence, reminiscence)	Qualitative & Quantitative Analyses of Verbal Behavior	PLwD & Care Partner	X	X	
Non-verbal Communication (e.g., gestures, facial expressions)	Qualitative & Quantitative Analyses of Non-Verbal Behavior	PLwD	X	X	
Secondary					
Quality of Life	QoL-AD	PLwD* & Care Partner	X		X
Well-Being	WHO-5	PLwD* & Care Partner	X		X
Caregiver Burden	Short Zarit Burden Interview	Care Partner	X		X
Usability/Preference	System Usability Scale	PLwD* & Care Partner		X	X

*Questionnaire can be completed for PLwD by care partners as proxy if necessary.

[1] VIMSSQ: Visually Induced Motion Sickness Questionnaire [28,29]

[2] MPC-D & MSC-D: Measure of Participation and Support in Conversation for Dementia [27]

[3] QoL-AD: Quality of Life – Alzheimer's Disease scale

Data Analyses

We will employ a mixed-methodology approach involving both qualitative and quantitative measures.

Qualitative Analyses

The video recording of the teleconference sessions will be transcribed by members of the research team. Verbal communication will be transcribed verbatim and non-verbal communication will also be tagged during transcription [30]. Next, two coders will analyze all the transcripts. Thematic analyses will be conducted, which involve analyzing, examining, and recording patterns (or 'themes') within the data [31]. They will use a combination of deductive and inductive methods to code the data [32]. After the two coders analyze the transcripts separately, the data will be merged to identify and resolve discrepancies between coders. The coding of both verbal and non-verbal behavior for this study will be conducted through NVivo software.

Quantitative Analyses

First, we will examine the data collected from the baseline measures and report the descriptive statistics. The analyses for all our continuous outcome measures, when possible, will account for by-subject variability in the statistical model using advanced statistical techniques such as linear mixed effect models, including the experimental condition as a fixed factor (VR, Tablet-only). Follow-up planned comparisons will also be reported for any observed significant effects. In addition, all the baseline measures (e.g., sex, gender, type of dementia) will be used as covariates to judge whether these measures are associated with participants' performance on the communication and well-being outcomes.

Ethics and Dissemination

The study has received ethical approval through the University Health Network (# 21-5701). The outcome of the study will be shared through peer-reviewed journal manuscripts, national and international conference and public presentations, university and hospital-based newsletters, and media outlets.

Discussion

With a significant rise in research revealing the potential usefulness and feasibility of VR for different aspects of dementia-related interventions, it is expected that VR use may increase in home settings. The planned intervention provides a new application for VR as a "ticket to talk", intended to elicit and enhance conversations and reminiscence, which in turn is expected to improve general well-being in both PLwD and their care partners. By comparing performance across the different conditions (VR vs. Tablet-only), and different VR content themes (e.g., travel vs. animals), we can also determine the preferences of individuals within this population, which is essential for ensuring prolonged benefits of this intervention. The results of this study will not only inform clinical applications of VR technology but will also help in the future design and development of VR systems and content for PLwD.

Authors' Contribution

Study conceptualization: RS, LA, and JC. Design of materials: RS, LA, SL, QD, EG, JC. Drafting of the initial manuscript: RS and JC. Critical revision of the manuscript: RS, LA, SL, JN, JC. All authors read and approved the final manuscript.

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Competing Interests

The authors have no conflicts of interest to declare.

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VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

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VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

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ABSTRACT

Introduction: Virtual Reality (VR) technology is increasingly used by researchers and healthcare professionals as therapeutic interventions to improve the quality of life of persons living with dementia (PLwD). However, most VR interventions to date have mainly been explored in long-term or community care settings, with fewer being explored at home. Setting is important given that the majority of PLwD live at home and are cared for by their family care partners. One of the challenges affecting PLwD and care partner relationships is barriers in communication, which can lead to social isolation and poor quality of life for both parties. Thus, the goal of the proposed project is to explore whether an immersive, multisensory VR intervention can facilitate communication between PLwD and their care partners and, in turn, enhance personal relationships and improve well-being.

Methods and analysis: Thirty dyads comprised of individuals living with dementia and their family/friend care partners will participate in this at-home intervention. Their interactions will be recorded as they watch a series of 360-degree videos together (e.g., concert, travel) either using a VR headset (PLwD) with a paired tablet (care partner) or using only a tablet together. The two conditions will allow us to compare immersive VR-technology to more common non-immersive Tablet-based technology. The study will begin with at-home training and baseline data collection. The intervention will then take place over a 4-week period, with the two conditions (VR vs. Tablet-only) experienced two weeks each. A comprehensive set of measures will be employed to assess the quality and quantity of dyadic interactions, such as verbal/non-verbal language (e.g., informativity, gestures), and self-reported measures of well-being and quality of life.

Ethics and dissemination: Ethical approval for the study was granted by the University Health Network (# 21-5701). Findings will be shared with all stakeholders through peer-reviewed publications and presentations.

Strengths and Limitations of the Study:

- Strengths: The findings will inform both the utilization of VR technology for therapeutic purposes and the future design of VR systems and content for PLwD, particularly for use in a home setting.
- Evaluating a non-pharmacological, at-home intervention could specifically improve interpersonal relationships between PLwD and care partners, which has not yet been fully explored as a key outcome.
- Whereas previous VR studies have evaluated beneficial effects of VR interventions, very few have considered whether immersive VR technologies result in better outcomes than traditional display technologies (e.g., tablets).
- Weaknesses: Participating care partners will comprise of English-speaking individuals living in the greater Toronto region and thus our findings may not be generalizable to the general population.
- To reduce the potential for simulator sickness and disorientation, the selected videos will not include any large-scale movements and consequently, the level of engagement may be less than other interactive VR experiences.

VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

INTRODUCTION

The number of individuals living with dementia is estimated at 50 million people globally and these numbers are expected to rise substantially with the increasing aging population [1,2]. Recent years have seen a significant rise in research exploring the use of head mounted Virtual Reality (VR) systems for persons living with dementia (PLwD) [see 3, for a review]. Some of this work has focused on exposing PLwD to immersive experiences in virtual environments (e.g., experiencing nature, travel, concerts and sporting events) with the goal of eliciting reminiscence and positive affect and improving overall well-being [3–10]. A unique aspect of this type of VRx-therapy (the use of VR as a therapeutic intervention) is that it allows PLwD to be transported to alternate realities and to have experiences that they may no longer be able to have because of the functional limitations that accompany their symptoms. To date, the evidence suggests that these exposure-based VRx-therapy interventions are feasible and have potential to decrease behavioral and psychological symptoms of dementia (e.g., aggression, agitation, depression), and improve PLwD's mood, well-being, and quality of life [4,6,8,11,12,12]. However, most of this evidence stems from studies that have taken place in the context of long-term care or community care settings where a researcher or a trained formal care provider administers the VRx-therapy. Relatively less is known about the utilization of VRx-therapy for PLwD in an at-home setting and in the context in which the family/friend care partner administers the intervention. This is an important context to explore as most PLwD live at home and are cared for by their family members [In Canada, 61% of PLwD live at home, 13], thus there is great potential for evaluating whether VRx-therapy can be prescribed as a non-pharmacological solution to address the needs of this population.

Over the past several years, members of our team have evaluated a prototype version of the VRx-therapy in several studies including a multi-site pilot feasibility study across several long-term care facilities and ambulatory out-patient clinics, involving 70 individuals with varying severities and types of cognitive and physical impairments [4–6]. Participants experienced 360-degree nature videos while wearing a head mounted VR system. In general, it was found that the intervention was feasible and well-tolerated by participants, who also reported feeling more relaxed after their VRx-therapy exposure sessions. One important, but somewhat unexpected, observation that emerged from this work was that the VR interventions appeared to increase interpersonal engagement of the users. Specifically, residents wanted to share their experiences with their formal care partners (e.g., nurses), visiting family members, and other residents. Other emerging evidence has demonstrated that experiencing realistic scenes and scenarios through VR is an effective strategy for reminiscence therapy in PLwD, leading to increased engagement, improved mood, and greater feelings of well-being [7,8,10,14–16]. However, VR interventions, while momentarily helpful, have also been described as potentially "isolating" in the sense that, in most cases, PLwD are experiencing them on their own. Indeed, the most meaningful real-world experiences are typically those that we share with others, especially our friends and families. Hodge and colleagues [17] recommended that future VR designs focus on "making room for sharing" and suggest that VR experiences may provide a "ticket to talk" (a tool to elicit conversation and increase engagement), which could lead to enhanced PLwD-care partner relationships. To our knowledge, the concept of VR as a "ticket to talk" in this population has not been empirically evaluated, or carefully measured as an outcome of VRx-therapy based interventions. Therefore, in the current study, we aim to use VR as a tool to facilitate communication between PLwD and family/friend care partners at home. This will be achieved by having PLwD and care partners jointly experience the content presented within the virtual environment, which will provide them with an opportunity to converse about their experiences. Specifically, care partners will be given a tablet which will mirror the viewing perspective of the PLwD's VR experience in real time. The shared VR intervention proposed here is expected to be beneficial not only for PLwD but also for care partners– something neither targeted nor measured in previous studies.

Barriers to communication is a key challenge that care partners face at home, and it negatively impacts care partners' relationships with PLwD. Communication barriers have been shown to lead to loneliness, social isolation, and poor quality of life for both PLwD and care partners [18–21]. There is some evidence that communication aids designed to elicit conversations (e.g., tools that present pictures, videos, music), are effective at improving interactions between PLwD and care partners [22,23]. Most of these interventions, however, have focused on other types of technology-based aids such as applications for phones and tablets [22,24] and digital memory books containing generic or personal photographs [25]. One aspect of VR that makes it unique from other display technologies such as televisions, computers, and handheld mobile devices is the level of immersiveness that is achieved. Immersion in VR is related to the extent to which our senses are presented with simulated inputs from the virtual environment [26]. When wearing a VR head mounted display, the user's visual and auditory inputs are exclusive to the VR environment and isolated from the real-world inputs, thereby resulting in VR being more immersive than traditional tablet-based technology. The increased immersiveness in VR has shown to lead to a greater sense of presence (a feeling of being there), including in PLwD [27]. Recent evidence also suggests that immersive VR leads to increased positive affect, and greater reminiscence than traditional methods used for reminiscence therapies (e.g., picture book, listening to music) [28]. Furthermore, one of the key benefits of VR's immersiveness is that individuals can have new experiences that feel very real in a controlled and safe environment, such as in one's own home.

The proposed project explores whether an immersive, multisensory VR intervention focused on "sharing experiences together" can facilitate communication between PLwD and their care partners and, in turn, enhance interpersonal relationships and improve quality of life. Further, we will explore whether the added level of immersiveness provided through multisensory VR is even more effective at facilitating communication than non-immersive tablet-based technology, which is a more commonly used tool in communication and reminiscence therapies. Although both tools are capable of providing a "shared experience", it is not yet known whether one is more effective than the other in facilitating communication. VR is not only more immersive but also a novel technology that could be considered more fun and engaging by participating families. There are, however, other benefits that are unique to tablet technology such as being more familiar and easier to use. In addition, while using the tablet together, PLwD and care partners can engage in joint attention and exchange more nonverbal behavior (gaze, facial expression), which are integral aspects of everyday interaction that could further facilitate verbal communication.

OBJECTIVES AND PREDICTIONS

The overarching goal of the current study is to design and evaluate a virtual reality at-home intervention to facilitate communication between PLwD and their care partners, and in turn improve their interpersonal relationships and quality of life. In particular, we are interested in examining whether VRx-therapy could help elicit and maintain conversations, increase positive affect, and evoke reminiscence through the sharing of memories. The project also aims to provide a direct comparison of an immersive VR system with non-immersive tablet-based technology.

In addition to collecting self-report measures of communication and well-being, we will introduce a picture book session to capture baseline measures of communication between PLwD and care partners. Comparisons between the VR and Tablet-only conditions will be made relative to these baseline measures. We predict that relative to baseline, both VR and Tablet-only conditions will facilitate communication, as these technologies provide a greater multisensory experience. Specifically, they include extra sensory input through audio, as well as have dynamic scenes that allow for multiple viewing perspectives (similar to real-world experiences). In terms of the VR and Tablet-only comparison, one possible outcome is that the VR condition, which is more immersive, will be more likely to evoke reminiscence, elicit positive affect, and increase presence, which in turn would lead to enhanced verbal (e.g., longer conversations) and non-verbal (e.g., more laughs) communication than the Tablet-only condition. Another possibility is that the Tablet-only condition will be more likely than the VR condition to elicit conversations and reminiscence because the PLwD and care partner can engage more in nonverbal communication (eye-contact, facial expressions). Finally, we anticipate that an increase in communication and reminiscence will in turn have a positive impact on users' well-being and positive perceptions of the experiences with both technologies.

METHODS

Participant, family, and community involvement

We will employ a participatory design method by actively engaging PLwD, family care partners, and community care partners in every stage of our study (from design to implementation to data interpretation). We have also consulted with members of our multidisciplinary team who have expertise in hearing, vision, communication, and technology. These members include scientists with expertise in audiology, optometry, and speech language pathology. These stakeholders have assisted us with the selection, design, and development of the VR content and assessment techniques. After creating the content, we collected preliminary ratings of each video's audio/visual quality, interest, and discomfort/side effects. Recently, we also completed a pilot study with seven PLwD-care partner dyads (5 completed the full study, 2 dropped out due to lack of interest or time) to explore the feasibility of this at-home intervention and to collect feedback on the digital content, study materials and procedures. We have updated the study materials and procedures based on the feedback we received from both PLwD and care partners. One of these changes involved simplifying the study to include fewer interviews and questionnaires, thus reducing the demand on care partners. Other changes were more specific to increasing the types of content that were considered more engaging (for example, increasing the number of videos with singing and dancing). The results of the pilot study are described in separate publications [29].

Participants

Thirty individuals with dementia and thirty care partners (friend or family members of the PLwD) will be recruited to participate in the study. As part of the recruitment plan, printed flyers will be posted throughout the community surrounding the greater Toronto region (e.g., hospitals, local university campuses, community centers, and libraries). Digital flyers will be disseminated via websites, social media, and through our community partners. Efforts will be made to recruit equal samples of male and female PLwD and care partners, allowing for further analyses exploring group level differences and understanding how sex/gender may affect the intervention outcomes. In addition, given that vision and hearing abilities play an important role in our intervention and are known to be particularly prevalent in

PLwD, we will specifically collect information on participants' sensory abilities. This will allow us to explore whether the observed outcomes are in any way influenced by sensory abilities.

Eligibility Criteria

Given the nature of the study, the participating dyads will be required to have access to high-speed internet with a reliable WiFi connection. Additional inclusion/exclusion criteria are as follows:

PLwD inclusion criteria:
- report having dementia
- currently living at home

PLwD exclusion criteria:
- recent history of seizure, epilepsy, head trauma, or stroke
- pacemaker
- cervical conditions or injuries
- open face wounds
- alcohol-related dementia/Korsakoff syndrome
- having a Public Guardian and Trustee as substitute decision maker

The above health-related exclusion criteria are specifically selected as a safety precautions for wearing a VR headset.

Care partner inclusion criteria:
- identify as one of the primary care partners for the PLwD
- able to speak and understands English

Care partner exclusion criteria:
- professional/formal care partners for the PLwD
- unable to provide informed consent

Materials and Apparatus

The study will have one main within-participant experimental manipulation, namely every participant will experience the presentation of different visual media: VR vs. Tablet-only for intervention and standard picture book for baseline.

Picture Book

To capture baseline measures of communication between PLwD and care partners, participants will be presented with a photo album containing high-quality prints representing themes from scenes that will be viewed on the Tablet/VR.

Tablet

PLwD and care partners will view non-immersive 360-degree videos together using a commercially available Samsung Tablet. PLwD will be able to move the position and perspective of the virtual environment using the touch screen (dragging the view around with their finger). All 360-degree videos (described below) will be uploaded to the Tablet and played using the VRx@Home study app, specifically designed for this at-home intervention. The custom app has a simple interface and is accessed by participants via a unique login. This login will enable us to control the selection of videos accessible to participants for each particular week of the intervention, and anonymously track their usage (i.e., by name of the videos selected and length of time watched; see the study website for a demonstration of the app).

VR

PLwD will view immersive VR experiences (360-degree videos) using an Oculus Quest 2 VR system that has built-in, over-ear headphones. The PLwD will be watching dynamic videos from a static position and although they will remain in one location within a scene, they will have the ability to look 360-degrees around and explore through head movements and thus change their perspective in the scene. However, they will not be able to translate or teleport within the scene or move from a stationary, seated position in the real world. This method significantly reduces the chance of feeling motion sickness in VR.

The care partner will be seated nearby to ensure the safety of the PLwD and to jointly experience the virtual content on a paired tablet mirroring the VR display. As such, the care partner will be able to see the content of VR from the exact same perspective as the PLwD but will not be able to manipulate the viewing perspective. In addition, the care partner will use the tablet to select the videos and stop the session if there are any concerns for safety or any signs of distress from the PLwD. (see Figure 1)

Recording Tools

Video and audio recordings will be captured through a video-conferencing application. We will follow recommended guidelines to set up a secured conference call (via Zoom) on a supplied laptop. If the researchers find it difficult to hear the PLwD during the initial Zoom meeting, then a digital audio recorder will also be provided. In this case, participants will be asked to place the digital recorder closer to the PLwD as a backup device to capture the conversations. All recordings will use anonymized participant IDs. PLwD and care partners will be given a journal and asked to record personal reflections about the sessions to capture any feelings, observations, or opinions about the VR, the Tablet, or the experience in general not otherwise collected by the study tools.

Visual and Auditory Stimuli

We created an extensive library of scenarios (360-degree videos with sound) that are each approximately 5 minutes long (84 videos). These scenarios are broadly categorized into four themes: Entertainment (e.g., ballet, musical concerts), animals (e.g., dogs, giraffes), travel (e.g., Niagara Falls, Paris), and sports (e.g., baseball, gymnastics). Participants will be presented with four of these 5-minute scenarios during their initial weekly exposure sessions (20 minutes total viewing). The 20-minute total duration is the median length of time employed in most VR studies with PLwD [see 3, for a review]. This duration was chosen to allow engagement while preventing fatigue. The pairings of scenarios to condition (VR or the Tablet-only) will be systematically structured. This will ensure that a particular scenario is only presented once to each participant, and thus, will be novel. The particular themes and order of videos will be pre-established in separate lists. To control for order effects, there will be four lists, for Lists 1 and 3 VR will be experienced first, for Lists 2 and 4 Tablet-only will be experienced first. Each of the four themes (entertainment, animals, travel, and sports) will be introduced in a different order across lists. Participants will be sequentially randomized to one of these ordered lists as they are recruited. For example, participant 1 will be in List 1, participant 2 in List 2, etc. In addition, participants will have access to a library of at least 21 videos per theme to choose from for their every-other-day experiences (described below).

Study Phases and Procedures

The full study will be approximately 5 weeks long per participant dyad. The intervention phase will be 4-weeks long, with an additional week allocated for pre-screening participants and at-home visits. In total, there will be 3 at-home visits where the researchers will drop off equipment and provide training (week 0), switch devices (VR or Tablet-only condition) and provide additional training, if necessary (week 2), and pick up the equipment (week 5). The rest of the intervention will be conducted fully remotely through online video-conferencing software, online questionnaires, and journaling. See Figure 2 for a summary of the study procedures and timeline.

Pre-Intervention

After eligibility is confirmed over a pre-screening telephone interview and informed consent is provided, we will schedule the first equipment drop-off and training session conducted in person. During this session, we will provide training on how to use the devices and video-record the study sessions. We will also show participants how to access and complete the questionnaires/surveys through the application on the supplied laptop. The PLwD and care partner will be asked to view the picture book together and record their interactions via the video-conferencing software. The picture book not only serves as our baseline control condition, but it also allows the participants to become familiarized with the video conferencing tool that they will use during sessions with the researcher. In addition, the researchers will test the quality of video and audio during this session and determine whether the backup digital recorder is necessary.

Intervention

The next four weeks will be the intervention phase where participating dyads will either receive a VR device (plus mirrored tablet) or only the Tablet device for two weeks (weeks 1 and 2), and then receive the other device (VR device or Tablet-only) in the following two weeks (weeks 3 and 4). Across the VR/Tablet conditions, participants will be asked to simply watch the videos and explore the content through head movements (VR) and touch screen navigation (Tablet) as desired.

Beginning every week, we will audio and video record PLwD-care partner interactions (verbal and non-verbal language) during the Tablet/VR experience. This weekly exposure session will include 20 minutes of viewing the pre-determined video sequence, followed by a feedback interview conducted by the researcher regarding their experiences and preferences. Participants will then be asked to use the system every other day by choosing from a selection of videos made available to them on the app (17 additional videos per theme in addition to the four videos they will watch with the researcher). They will be asked to continue recording their interactions as they watch these videos on their own (3 times per week x 20 minutes each). Finally, they will be asked to complete online questionnaires regarding communication and measures of well-being after each phase of the intervention (VR vs. Tablet-only).

Study-Completion

On the final week of the study (Week 5), we will conduct a formal interview virtually to evaluate the feasibility and effectiveness of the intervention and then make a final home visit collect the equipment.

Outcome Measures

Table 1 provides an overview of all outcome measures and the phase of the protocol during which they will be administered.

Baseline Measures

We will first collect measures on demographics, general health, technology use, and cybersickness susceptibility using questionnaires and semi-structured interviews. Apart from cybersickness (only asked of PLwD), all these measures will be collected from both the PLwD and their care partner.

Primary Measures: Verbal and Non-Verbal Communication

Our primary outcomes of interest are measures of verbal and non-verbal communication captured through audio and video recordings as well as self-reported through questionnaires and journal entries. These data will be collected throughout the intervention and evaluated using standardized scales, thematic analyses, and coding schemes developed specifically for the study. The following characteristics of verbal and non-verbal communication will be measured:

Verbal:

- Quality of conversation and dyadic interactions as assessed through questionnaires:
    - Measure of Participation in Conversation for Dementia (MPC-D) [30]
    - Measure of Support in Conversation for Dementia (MSC-D) [30]
    - Custom communication questionnaire
- Language performance measures:
    - Utterance length (total duration and mean length of utterance)

  - Conversation initiation (count of how many times PLwD initiated conversation)
  - Fluency (amount and type of disfluency)
  - Coherence/Informativity (topic maintenance, off-topic verbosity)
  - Affect in language (sentiment analyses)
- Reminiscence/Storytelling (number and the length of episodic memories)

Non-verbal:

- Facial expressions (frequency of smiles/laughter, frowns/grimaces)
- Gestures (e.g., frequency and type of gestures)

Secondary Measures: Well-Being and Quality of Life

Measures of well-being and quality of life (e.g., relationship quality, mood, mental health), will be assessed through standardized questionnaires (see Table 1). Both PLwD and care partners will complete these measures pre- and post- each phase of the intervention (bi-weekly following each Tablet-only and VR condition). In addition, interviews will be conducted to capture any feelings, observations, or opinions about the VR/Tablet-only experiences, or the study materials/procedures not otherwise captured by the study tools.

Secondary Measures: Preference and Usability

We will use standardized measures, semi-structured interviews, and information provided in the journal to assess participants' opinions of the devices and experiences (e.g., device tolerance/comfort, content preference, challenges and areas for improvement).

Table 1: Summary of all Outcome Measures

Outcome Measure Categories	Instrument and Measurement Tools	Participant Group	Time Point		
			Pre-Intervention	*Intervention (weekly)*	*Post-Intervention (bi-weekly)*
Baseline					
Demographic & Health	Demographic & Health Survey	PLwD* & Care Partner	X		
Technology Use & Comfort	Technology Survey	PLwD* & Care Partner	X		
Cybersickness Susceptibility	VIMSSQ-short[1]	PLwD*	X		
Primary					
Dyadic interactions (e.g., conversation quality, participation, support, & engagement)	-MPC-D & MSC-D -Communication Survey	PLwD & Care Partner	X	X	
Verbal Communication (e.g., utterance length, coherence, reminiscence)	Qualitative & Quantitative Analyses of Verbal Behavior	PLwD & Care Partner	X	X	
Non-verbal Communication (e.g., gestures, facial expressions)	Qualitative & Quantitative Analyses of Non-Verbal Behavior	PLwD	X	X	
Secondary					
Quality of Life	QoL-AD	PLwD* & Care Partner	X		X
Well-Being	WHO-5	PLwD* & Care Partner	X		X
Caregiver Burden	Short Zarit Burden Interview	Care Partner	X		X
Usability/Preference	System Usability Scale	PLwD* & Care Partner			X

*Questionnaire can be completed for PLwD by care partners as proxy if necessary.
[1]VIMSSQ: Visually Induced Motion Sickness Questionnaire [31,32]
[2]MPC-D & MSC-D: Measure of Participation and Support in Conversation for Dementia [30]
[3]QoL-AD: Quality of Life – Alzheimer's Disease scale

Data Monitoring

The data from the study as captured through video recordings, questionnaires, and journal entries will all be verified and backed up by a research coordinator. In addition to regular reminders, participants will receive further reminders through emails and/or phone calls for completing any outstanding questionnaires and on-own sessions. Research assistants completing interviews will flag any major concerns raised by families during interviews and will inform the principal investigators immediately so these concerns can be addressed. All transcribers, translators, and coders will be trained by the research coordinator or principal investigator.

Data Analyses

We will employ a mixed-methodology approach involving both qualitative and quantitative measures.

Qualitative Analyses

The video recording of the teleconference sessions will be transcribed by members of the research team. Verbal communication will be transcribed verbatim and non-verbal communication will also be tagged during transcription [33]. Translation services will be utilized for any sessions during which participants are not communicating in English. The video recordings will specifically be coded for any evidence of non-verbal behavior that is indicative of communication and engagement (e.g., laughter, humming, dancing, etc.). Next, two coders will analyze all the transcripts. Thematic analyses will be conducted, which involve analyzing, examining, and recording patterns (or 'themes') within the data [34]. They will use a combination of deductive and inductive methods to code the data [35]. In terms of the deductive methods, we will specifically code for instances of episodic memory (as a measure of reminiscence) and instances of initiating a conversation (as a measure of communication). After the two coders analyze the transcripts separately, the data will be merged to identify any discrepancies. The coders will discuss any discrepancies, and ask a third coder to resolve any discrepancies that they cannot resolve themselves. The coding of both verbal and non-verbal behavior for this study will be conducted through NVivo software.

Quantitative Analyses

First, we will examine the data collected from the baseline measures and report the descriptive statistics. The analyses for all our continuous outcome measures, when possible, will account for by-subject variability in the statistical model using advanced statistical techniques such as linear mixed effect models, including the experimental condition as a fixed factor (VR, Tablet-only). Follow-up planned comparisons will also be reported for any observed significant effects. In addition, all the baseline measures (e.g., sex, gender, type of dementia) will be used as covariates to judge whether these measures are associated with participants' performance on the communication and well-being outcomes.

Ethics and Dissemination

The study has received ethical approval through the University Health Network (# 21-5701). The outcome of the study will be shared through peer-reviewed journal manuscripts, national and international conference and public presentations, university and hospital-based newsletters, and media outlets.

Discussion

With a significant rise in research revealing the potential usefulness and feasibility of VR for different aspects of dementia-related interventions, it is expected that VR use may increase in home settings. The planned intervention provides a new application for VR as a "ticket to talk", intended to elicit and enhance conversations and reminiscence, which in turn is expected to improve general well-being in both PLwD and their care partners. By comparing performance across the different conditions (VR vs. Tablet-only), and different VR content themes (e.g., travel vs. animals), we can also determine the preferences of individuals within this population, which is essential for ensuring prolonged benefits of this intervention. The results of this study will not only inform clinical applications of VR technology but will also help in the future design and development of VR systems and content for PLwD.

Authors' Contribution

Study conceptualization: RS, LA, and JC. Design of materials: RS, LA, SL, LC, QD, EG, JC. Drafting of the initial manuscript: RS and JC. Critical revision of the manuscript: RS, LA, SL, LC, JC. All authors read and approved the final manuscript. JC is the guarantor.

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Competing Interests

The authors have no conflicts of interest to declare.

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Figures

Figure 1. Study Conditions and Materials

Note. Consent for photograph release was provided by the participants

Figure 2. Study Procedures and Timeline

Note. VR and Tablet-only conditions are experienced for two weeks each, in a counterbalanced order across participants.

Picture Book

Tablet

VR

Figure 1. Study Conditions and Materials

Note. Consent for photograph release was provided by the participants

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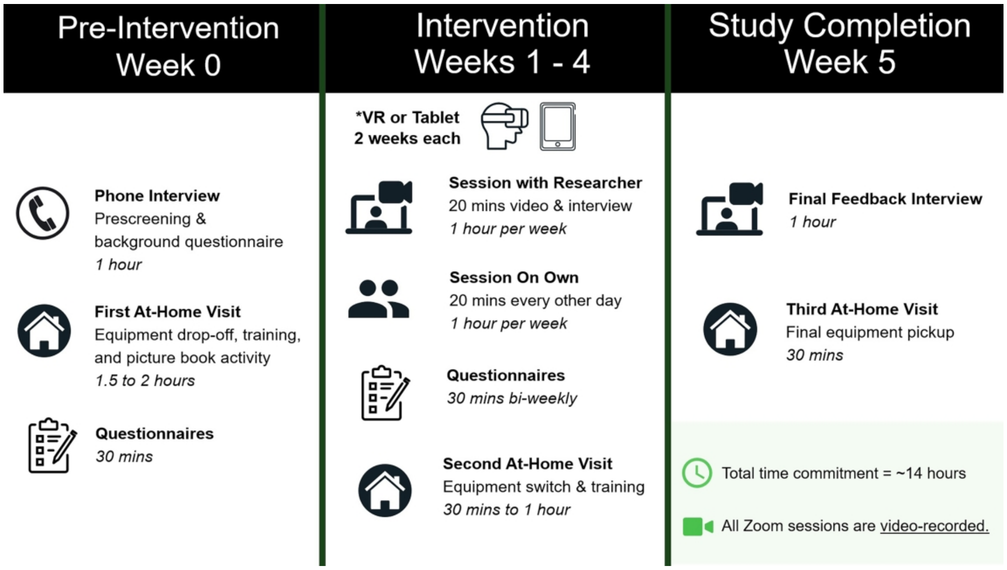

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Note. VR and Tablet-only conditions are experienced for two weeks each, in a counterbalanced order across participants.

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VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

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VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

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ABSTRACT

Introduction: Virtual Reality (VR) technology is increasingly used by researchers and healthcare professionals as therapeutic interventions to improve the quality of life of persons living with dementia (PLwD). However, most VR interventions to date have mainly been explored in long-term or community care settings, with fewer being explored at home. Setting is important given that the majority of PLwD live at home and are cared for by their family care partners. One of the challenges affecting PLwD and care partner relationships is barriers in communication, which can lead to social isolation and poor quality of life for both parties. Thus, the goal of the proposed project is to explore whether an immersive, multisensory VR intervention can facilitate communication between PLwD and their care partners and, in turn, enhance personal relationships and improve well-being.

Methods and analysis: Thirty dyads comprised of PLwD and their family/friend care partners will participate in this at-home intervention. Their interactions will be recorded as they experience a series of 360-degree videos together (e.g., concert, travel) either using a VR headset (PLwD) with a paired tablet (care partner) or using only a tablet together. The two conditions will allow us to compare immersive VR-technology to more common non-immersive tablet-based technology. The study will begin with at-home training and baseline data collection. The intervention will then take place over a 4-week period, with the two conditions (VR vs. Tablet-only) experienced two weeks each. A comprehensive set of measures will be employed to assess the quality and quantity of dyadic interactions, such as verbal/non-verbal language (e.g., informativity, gestures), and self-reported measures of well-being and quality of life.

Ethics and dissemination: Ethical approval for the study was granted by the University Health Network (# 21-5701). Findings will be shared with all stakeholders through peer-reviewed publications and presentations.

Clinical registration: This study has been registered on clinicaltrials.gov (NCT06568211).

Strengths and Limitations of the Study:

- VRx@Home is an immersive virtual reality intervention for persons living with dementia that takes place in a personal home setting.
- The study aims to facilitate communication between persons living with dementia and their family care partners, thus evaluating the effectiveness of the intervention on both parties.
- The study will allow for a direct comparison of immersive VR technology with traditional tablet-based technology.
- The selected videos will not include any large-scale movements to help reduce simulator sickness, consequently the level of engagement may be less than other interactive experiences.
- Participants will be from the greater Toronto region and thus findings may not be generalizable to the broader population.

VRx@Home Protocol: A Virtual Reality At-Home Intervention for Persons Living with Dementia and their Care Partners

INTRODUCTION

The number of individuals living with dementia is estimated at 50 million people globally and these numbers are expected to rise substantially with the increasing aging population [1,2]. Recent years have seen a significant increase in research exploring the use of head mounted Virtual Reality (VR) systems for persons living with dementia (PLwD) [see 3 for a review]. Some of this work has focused on exposing PLwD to immersive experiences in virtual environments (e.g., experiencing nature, travel, concerts and sporting events) with the goal of eliciting reminiscence and positive affect and improving overall well-being [3–10]. A unique aspect of this type of VRx-therapy (the use of VR as a therapeutic intervention) is that it allows PLwD to be transported to alternate realities and to have experiences that they may no longer be able to have because of the functional limitations that accompany their symptoms. To date, the evidence suggests that these exposure-based VRx-therapy interventions are feasible and have potential to decrease behavioral and psychological symptoms of dementia (e.g., agitation, depression), and improve PLwD's mood, well-being, and quality of life [4,6,8,11,12]. However, most of this evidence stems from studies that have taken place in the context of long-term care or community care settings where a researcher or a trained formal care provider administers the VRx-therapy. Relatively less is known about the utilization of VRx-therapy for PLwD in an at-home setting and in a context in which the family/friend care partner administers the intervention. This is an important context to explore as most PLwD live at home and are cared for by their family members [in Canada, 61% of PLwD live at home, 13], thus there is great potential for evaluating whether VRx-therapy can be prescribed as a non-pharmacological solution to address the needs of this population.

Over the past several years, members of our team have evaluated a prototype version of VRx-therapy in several studies including a multi-site pilot feasibility study across several long-term care facilities and ambulatory out-patient clinics, involving 70 individuals with varying severities and types of cognitive and physical impairments [4–6]. Participants experienced 360-degree nature videos while wearing a head mounted VR system. In general, it was found that the intervention was feasible and well-tolerated by participants, who also reported feeling more relaxed after their VRx-therapy exposure sessions. One important, but somewhat unexpected, observation that emerged from this work was that the VR interventions appeared to increase interpersonal engagement of the users. Specifically, residents wanted to share their experiences with their formal care partners (e.g., nurses), visiting family members, and other residents. Other emerging evidence has demonstrated that experiencing realistic scenes and scenarios through VR is an effective strategy for reminiscence therapy in PLwD, leading to increased engagement, improved mood, and greater feelings of well-being [7,8,10,14–16]. However, VR interventions, while momentarily helpful, have also been described as potentially "isolating" in the sense that, in most cases, PLwD are experiencing them on their own. Indeed, the most meaningful real-world experiences are typically those that we share with others, especially our friends and families. Hodge and colleagues [17] recommended that future VR designs focus on "making room for sharing" and suggest that VR experiences may provide a "ticket to talk" (a tool to elicit conversation and increase engagement), which could lead to enhanced PLwD-care partner relationships. To our knowledge, the concept of VR as a "ticket to talk" in this population has not been empirically evaluated, or carefully measured as an outcome of VRx-therapy based interventions. Therefore, in the current study, we aim to use VR as a tool to facilitate communication between PLwD and family/friend care partners at home. This will be achieved by having PLwD and care partners jointly experience the content presented within the virtual environment, which will provide them with an opportunity to converse about their experiences. Specifically, care partners will be given a tablet which will mirror the viewing perspective of the PLwD's VR experience in real time. The shared VR intervention proposed here is expected to be beneficial not only for PLwD but also for care partners, something neither targeted nor measured in previous studies.

Barriers to communication is a key challenge that care partners face at home, and it negatively impacts care partners' relationships with PLwD. Communication barriers have been shown to lead to loneliness, social isolation, and poor quality of life for both PLwD and care partners [18–21]. There is some evidence that communication aids designed to elicit conversations (e.g., tools that present pictures, videos, music), are effective at improving interactions between PLwD and care partners [22,23]. Most of these interventions, however, have focused on other types of technology-based aids such as applications for phones and tablets [22,24] and digital memory books containing generic or personal photographs [25]. One aspect of VR that makes it unique from other display technologies such as televisions, computers, and handheld mobile devices is the level of immersiveness that is achieved. Immersion in VR is related to the extent to which our senses are presented with simulated inputs from the virtual environment [26]. When wearing a VR head mounted display, the user's visual and auditory inputs are exclusive to the VR environment and isolated from the real-world inputs, thereby resulting in VR being more immersive than traditional tablet-based technology. The increased immersiveness in VR has shown to lead to a greater sense of presence (a feeling of being there), including in PLwD [27]. Recent evidence also suggests that immersive VR leads to increased positive affect, and greater reminiscence than traditional methods used for reminiscence therapies (e.g., picture book, listening to music) [28]. Furthermore, one of the key benefits of VR's immersiveness is that individuals can have new experiences that feel very real in a controlled and safe environment, such as in one's own home.

The proposed project explores whether an immersive, multisensory VR intervention focused on "sharing experiences together" can facilitate communication between PLwD and their care partners and, in turn, enhance interpersonal relationships and improve quality of life. Further, we will explore whether the added level of immersiveness provided through multisensory VR is even more effective at facilitating communication than non-immersive tablet-based technology, which is a more commonly used tool in communication and reminiscence therapies. Although both tools are capable of providing a "shared experience", it is not yet known whether one is more effective than the other in facilitating communication. VR is not only more immersive but also a novel technology that could be considered more fun and engaging by participating families. There are, however, other benefits that are unique to tablet technology such as being more familiar and easier to use. In addition, while using the tablet together, PLwD and care partners can engage in joint attention and exchange more nonverbal behavior (gaze, facial expression), which are integral aspects of everyday interaction that could further facilitate verbal communication.

OBJECTIVES AND PREDICTIONS

The overarching goal of the current study is to design and evaluate a virtual reality at-home intervention to facilitate communication between PLwD and their care partners, and in turn improve their interpersonal relationships and quality of life. In particular, we are interested in examining whether VRx-therapy could help elicit and maintain conversations, increase positive affect, and evoke reminiscence through the sharing of memories. The project also aims to provide a direct comparison of an immersive VR system with non-immersive tablet-based technology.

In addition to collecting self-report measures of communication and well-being, we will introduce a picture book session to capture baseline measures of communication between PLwD and care partners. Comparisons between the VR and Tablet-only conditions will be made relative to these baseline measures. We predict that relative to baseline, both VR and Tablet-only conditions will facilitate communication, as these technologies provide a greater multisensory experience. Specifically, they include extra sensory input through audio, as well as have dynamic scenes that allow for multiple viewing perspectives (similar to real-world experiences). In terms of the VR and Tablet-only comparison, one possible outcome is that the VR condition, which is more immersive, will be more likely to evoke reminiscence, elicit positive affect, and increase presence, which in turn could lead to enhanced verbal (e.g., longer conversations) and non-verbal (e.g., more laughs) communication than the Tablet-only condition. Another possibility is that the Tablet-only condition will be more likely than the VR condition to elicit conversations and reminiscence because the PLwD and care partner can engage more in nonverbal communication (eye-contact, facial expressions). Finally, we anticipate that an increase in communication and reminiscence will in turn have a positive effect on users' well-being and positive perceptions of the experiences with both technologies.

METHODS

Patient and Public Involvement

We will employ a participatory design method by actively engaging PLwD, family care partners, and community care partners in every stage of our study (from design to implementation to data interpretation). We have also consulted with members of our multidisciplinary team who have expertise in hearing, vision, communication, and technology. These members include scientists with expertise in audiology, optometry, and speech language pathology. These stakeholders have assisted us with the selection, design, and development of the VR content and assessment techniques. After creating the content, we collected preliminary ratings of each video's audio/visual quality, interest, and discomfort/side effects. Recently, we also completed a pilot study with seven PLwD-care partner dyads (5 completed the full study, 2 dropped out due to lack of interest or time) to explore the feasibility of this at-home intervention and to collect feedback on the digital content, study materials and procedures. We have updated the study materials and procedures based on the feedback we received from both PLwD and care partners. One of these changes involved simplifying the study to include fewer interviews and questionnaires, thus reducing the demand on care partners. Other changes were more specific to increasing the types of content that were considered more engaging (for example, increasing the number of videos with singing and dancing). The results of the pilot study are described in separate publications [29].

Participants

Thirty individuals living with dementia and thirty care partners (friend or family members of the PLwD) will be recruited to participate in the study. Because the goal of this study is to evaluate the intervention in a home setting, we initially aimed to recruit persons at the stages of dementia who were more likely to still be living at home with family care partners (i.e., mild to moderate, but not severe). However, given the interest in our study from persons living with severe dementia in an at-home setting, we have decided to expand our criteria to include all stages (mild, moderate, severe). We are encouraged by our previous research in long-term care settings [4,6] where even individuals with severe dementia can benefit from this intervention. Further, even within groups of individuals with mild, moderate, or severe stages of dementia, inter-individual variability and group heterogeneity is often high, and staging/diagnoses inconsistent; therefore, we want to be inclusive. Finally, as will be described below, the design intentionally controls for these potential inter-diagnostic group or inter-individual differences as best as possible. For example, we will use a within-subject design (with each person serving as their own control) and will include a set of baseline measures pre-intervention to compare pre versus post intervention differences within each individual.

As part of the recruitment plan, printed flyers will be posted throughout the community surrounding the greater Toronto region (e.g., hospitals, local university campuses, community centers, and libraries). Digital flyers will be disseminated via websites, social media, and through our community partners. Efforts will be made to recruit equal samples of male and female PLwD and care partners, allowing for further analyses exploring group level differences and understanding how sex/gender may affect the intervention outcomes. In addition, given that vision and hearing abilities play an important role in our intervention and are known to be particularly prevalent in PLwD, we will specifically collect information on participants' sensory abilities. This will allow us to explore whether the observed outcomes are in any way influenced by sensory abilities.

Eligibility Criteria

Given the nature of the study, the participating dyads will be required to have access to high-speed internet with a reliable WiFi connection. Additional inclusion/exclusion criteria are as follows:

PLwD inclusion criteria:
- report having dementia
- currently living at home

PLwD exclusion criteria:
- recent history of seizure, epilepsy, head trauma, or stroke
- pacemaker
- cervical conditions or injuries
- open face wounds
- alcohol-related dementia/Korsakoff syndrome
- having a Public Guardian and Trustee as substitute decision maker

The above health-related exclusion criteria are specifically selected as safety precautions for wearing a VR headset.

Care partner inclusion criteria:
- identify as one of the primary care partners for the PLwD
- able to speak and understand English

Care partner exclusion criteria:
- professional/formal care partners for the PLwD
- unable to provide informed consent

Materials and Apparatus

The study will have one main within-participant experimental manipulation, namely every participant will experience the presentation of different visual media: VR vs. Tablet-only for intervention and standard picture book for baseline.

Picture Book

To capture baseline measures of communication between PLwD and care partners, participants will be presented with a photo album containing high-quality prints representing themes from scenes that will be viewed on the Tablet/VR.

Tablet

PLwD and care partners will view non-immersive 360-degree videos together using a commercially available Samsung Tablet. PLwD will be able to move the position and perspective of the virtual environment using the touch screen (dragging the view around with their finger). All 360-degree videos (described below) will be uploaded to the tablet and played using the VRx@Home study app, specifically designed for this at-home intervention. The custom app has a simple interface and is accessed by participants via a unique login. This login will enable us to control the selection of videos accessible to participants for each particular week of the intervention, and anonymously track their usage (i.e., by name of the videos selected and length of time watched; see the study website for a demonstration of the app).

VR

PLwD will view immersive VR experiences (360-degree videos) using an Oculus Quest 2 VR system that has built-in headphones. The PLwD will be watching dynamic videos from a static position and although they will remain in one location within a scene, they will have the ability to look 360-degrees around and explore through head movements and thus change their perspective in the scene. However, they will not be able to translate or teleport within the scene or move from a stationary, seated position in the real world. This method significantly reduces the chance of feeling motion sickness in VR.

The care partner will be seated nearby to ensure the safety of the PLwD and to jointly experience the virtual content on a paired tablet mirroring the VR display. As such, the care partner will be able to see the content of VR from the exact same perspective as the PLwD but will not be able to manipulate the viewing perspective. In addition, the care partner will use the tablet to select the videos and stop the session if there are any concerns for safety or any signs of distress from the PLwD.

Recording Tools

Video and audio recordings will be captured through a video-conferencing application. We will follow recommended guidelines to set up a secured conference call (via Zoom) on a supplied laptop. If the researchers find it difficult to hear the PLwD during the initial Zoom meeting, then a digital audio recorder will also be provided. In this case, participants will be asked to place the digital recorder closer to the PLwD as a backup device to capture the conversations. All recordings will use anonymized participant IDs. PLwD and care partners will be given a journal and asked to record personal reflections about the sessions to capture any feelings, observations, or opinions about the VR, the Tablet, or the experience in general not otherwise collected by the study tools.

Visual and Auditory Stimuli

We created an extensive library of scenarios (360-degree videos with sound) that are each approximately 5 minutes long (84 videos). These scenarios are broadly categorized into four themes: Entertainment (e.g., ballet, musical concerts), animals (e.g., dogs, giraffes), travel (e.g., Niagara Falls, Paris), and sports (e.g., baseball, gymnastics). Participants will be presented with four of these 5-minute scenarios during their initial weekly exposure sessions (20 minutes total viewing). The 20-minute total duration is the median length of time employed in most VR studies with PLwD [see 3, for a review]. This duration was chosen to allow engagement while preventing fatigue. The pairings of scenarios to condition (VR or Tablet-only) will be systematically structured. This will ensure that a particular scenario is only presented once to each participant, and thus, will be novel. The particular themes and order of videos will be pre-established in separate lists. To control for order effects, there will be four lists, for Lists 1 and 3 VR will be experienced first, for Lists 2 and 4 Tablet-only will be experienced first. Each of the four themes (entertainment, animals, travel, and sports) will be introduced in a different order across lists. Participants will be sequentially randomized to one of these ordered lists as they are recruited. For example, participant 1 will be in List 1, participant 2 in List 2, etc. In addition, participants will have access to a library of at least 21 videos per theme to choose from for their every-other-day experiences (described below).

Study Phases and Procedures

The full study will be approximately 5 weeks long per participant dyad. The intervention phase will be 4-weeks long, with an additional week allocated for pre-screening participants and at-home visits. In total, there will be 3 at-home visits where the researchers will drop off equipment and provide training (week 0), switch devices (VR or Tablet-only condition) and provide additional training, if necessary (week 2), and pick up the equipment (week 5). The rest of the intervention will be conducted fully remotely through online video-conferencing software, online questionnaires, and journaling. See Figure 2 for a summary of the study procedures and timeline.

Pre-Intervention

After eligibility is confirmed over a pre-screening telephone interview and informed consent is provided, we will schedule the first equipment drop-off and training session conducted in person. During this session, we will provide training on how to use the devices and video-record the study sessions. We will also show participants how to access and complete the questionnaires/surveys through the application on the supplied laptop. The PLwD and care partner will be asked to view the picture book together and record their interactions via the video-conferencing software. The picture book not only serves as our baseline control condition, but it also allows the participants to become familiarized with the video conferencing tool that they will use during sessions with the researcher. In addition, the researchers will test the quality of video and audio during this session and determine whether the backup digital recorder is necessary.

Intervention

The next four weeks will be the intervention phase where participating dyads will either receive a VR device (plus mirrored tablet) or only the Tablet device for two weeks (weeks 1 and 2), and then receive the other device (VR device or Tablet-only) in the following two weeks (weeks 3 and 4). Across the

VR/Tablet conditions, participants will be asked to simply watch the videos and explore the content through head movements (VR) and touch screen navigation (Tablet) as desired.

Beginning every week, we will audio and video record PLwD-care partner interactions (verbal and non-verbal language) during the Tablet/VR experience. This weekly exposure session will include 20 minutes of viewing the pre-determined video sequence, followed by a feedback interview conducted by the researcher regarding their experiences and preferences. Participants will then be asked to use the system every other day by choosing from a selection of videos made available to them on the app (17 additional videos per theme in addition to the four videos they will watch with the researcher). They will be asked to continue recording their interactions as they watch these videos on their own (3 times per week x 20 minutes each). Finally, they will be asked to complete online questionnaires regarding communication and measures of well-being after each phase of the intervention (VR vs. Tablet-only).

Study-Completion

On the final week of the study (Week 5), we will conduct a formal interview virtually to evaluate the feasibility and effectiveness of the intervention and then make a final home visit to collect the equipment.

Outcome Measures

Table 1 provides an overview of all outcome measures and the phase of the protocol during which they will be administered.

Baseline Measures

We will first collect measures on demographics, general health, technology use, and cybersickness susceptibility using questionnaires and semi-structured interviews. Apart from cybersickness (only asked of PLwD), all these measures will be collected from both the PLwD and their care partner.

Primary Measures: Verbal and Non-Verbal Communication

Our primary outcomes of interest are measures of verbal and non-verbal communication captured through audio and video recordings as well as self-reported through questionnaires and journal entries. These data will be collected throughout the intervention and evaluated using standardized scales, thematic analyses, and coding schemes developed specifically for the study. The following characteristics of verbal and non-verbal communication will be measured:

Verbal:

- Quality of conversation and dyadic interactions:
  - Observational
    - Measure of Participation in Conversation for Dementia (MPC-D) [30]
    - Measure of Support in Conversation for Dementia (MSC-D) [30]
  - Self-report
    - Custom communication questionnaire
- Language performance measures:
    - Utterance length (total duration and mean length of utterance)

    - Conversation initiation (count of how many times PLwD initiated conversation)
    - Fluency (amount and type of disfluency)
    - Coherence/Informativity (topic maintenance, off-topic verbosity)
    - Affect in language (sentiment analyses)
- Reminiscence/Storytelling (number and length of episodic memories)

Non-verbal:

- Facial expressions (frequency of smiles/laughter, frowns/grimaces)
- Gestures (e.g., frequency and type of gestures)

Secondary Measures: Well-Being and Quality of Life

Measures of well-being and quality of life (e.g., relationship quality, mood, mental health), will be assessed through standardized questionnaires (see Table 1). Both PLwD and care partners will complete these measures pre- and post- each phase of the intervention (bi-weekly following each Tablet-only and VR condition). Care partners will also complete a caregiver burden questionnaire pre- and post- each intervention phase. In addition, interviews will be conducted to capture any feelings, observations, or opinions about the VR/Tablet-only experiences, or the study materials/procedures not otherwise captured by the study tools.

Secondary Measures: Preference and Usability

We will use standardized measures, semi-structured interviews, and information provided in the journal to assess participants' opinions of the devices and experiences (e.g., device tolerance/comfort, content preference, challenges and areas for improvement).

Table 1: Summary of all Outcome Measures

Outcome Measure Categories	Instrument and Measurement Tools	Participant Group	Time Point		
			Pre-Intervention	*Intervention (weekly)*	*Post-Intervention (bi-weekly)*
Baseline					
Demographic & Health	Demographic & Health Survey	PLwD* & Care Partner	X		
Technology Use & Comfort	Technology Survey	PLwD* & Care Partner	X		
Cybersickness Susceptibility	VIMSSQ-short[1]	PLwD*	X		
Primary					
Conversation Quality (Observational)	MPC-D & MSC-D[2]	PLwD & Care Partner	X	X	
Conversation Quality (Self-report)	Communication Survey	PLwD & Care Partner	X		X
Verbal Communication (e.g., utterance length, coherence, reminiscence)	Qualitative & Quantitative Analyses of Verbal Behavior	PLwD & Care Partner	X	X	
Non-verbal Communication (e.g., gestures, facial expressions)	Qualitative & Quantitative Analyses of Non-Verbal Behavior	PLwD	X	X	
Secondary					
Quality of Life	QoL-AD[3]	PLwD* & Care Partner	X		X
Well-Being	WHO-5	PLwD* & Care Partner	X		X
Caregiver Burden	Short Zarit Burden Interview	Care Partner	X		X
Usability/Preference	System Usability Scale	PLwD* & Care Partner			X

*Questionnaire can be completed for PLwD by care partners as proxy if necessary.
[1] VIMSSQ: Visually Induced Motion Sickness Questionnaire [31,32]
[2] MPC-D & MSC-D: Measure of Participation and Support in Conversation for Dementia [30]
[3] QoL-AD: Quality of Life – Alzheimer's Disease scale

Data Monitoring

The data from the study as captured through video recordings, questionnaires, and journal entries will all be verified and backed up by a research coordinator. In addition to regular reminders, participants will receive further reminders through emails and/or phone calls for completing any outstanding questionnaires and on-own sessions. Research assistants completing interviews will flag any major concerns raised by families during interviews and will inform the principal investigators immediately so these concerns can be addressed. All transcribers, translators, and coders will be trained by the research coordinator or principal investigator.

Data Analyses

We will employ a mixed-methodology approach involving both qualitative and quantitative measures.

Qualitative Analyses

The video recording of the teleconference sessions will be transcribed by members of the research team. Verbal communication will be transcribed verbatim and non-verbal communication will also be tagged during transcription [33]. Translation services will be utilized for any sessions during which participants are not communicating in English. The video recordings will specifically be coded for any evidence of non-verbal behavior that is indicative of communication and engagement (e.g., laughter, humming, dancing, etc.). Next, two coders will analyze all the transcripts. Thematic analyses will be conducted, which involve analyzing, examining, and recording patterns (or 'themes') within the data [34]. They will use a combination of deductive and inductive methods to code the data [35]. In terms of the deductive methods, we will specifically code for instances of episodic memory (as a measure of reminiscence) and instances of initiating a conversation (as a measure of communication). After the two coders analyze the transcripts separately, the data will be merged to identify any discrepancies. The coders will discuss any discrepancies and ask a third coder to resolve any discrepancies that they cannot resolve themselves. The coding of both verbal and non-verbal behavior for this study will be conducted through NVivo software.

Quantitative Analyses

First, we will examine the data collected from the baseline measures and report the descriptive statistics. The analyses for all our continuous outcome measures, when possible, will account for by-subject variability in the statistical model using advanced statistical techniques such as linear mixed effect models, including the experimental condition as a fixed factor (VR, Tablet-only). Follow-up planned comparisons will also be reported for any observed significant effects. In addition, all the baseline measures (e.g., sex, gender, type of dementia) will be used as covariates to judge whether these measures are associated with participants' performance on the communication and well-being outcomes.

Ethics and Dissemination

The study has received ethical approval through the University Health Network (# 21-5701). The outcome of the study will be shared through peer-reviewed journal manuscripts, national and international conferences and public presentations, university and hospital-based newsletters, and media outlets.

Discussion

With a significant rise in research revealing the potential usefulness and feasibility of VR for different aspects of dementia-related interventions, it is expected that VR use may increase in home settings. The planned intervention provides a new application for VR as a "ticket to talk", intended to elicit and enhance conversations and reminiscence, which in turn is expected to improve general well-being in both PLwD and their care partners. By comparing performance across the different conditions (VR vs. Tablet-only), and different VR content themes (e.g., travel vs. animals), we can also determine the preferences of individuals within this population, which is essential for ensuring prolonged benefits of this intervention. The results of this study will not only inform clinical applications of VR technology but will also help in the future design and development of VR systems and content for PLwD.

Authors' Contribution

Study conceptualization: RS, LA, and JC. Design of materials: RS, LA, SL, LC, DQ, EG, JC. Drafting of the initial manuscript: RS and JC. Critical revision of the manuscript: RS, LA, SL, LC, JC. All authors read and approved the final manuscript and JC is the guarantor.

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Competing Interests

The authors have no conflicts of interest to declare.

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Figures

Figure 1. Study Conditions and Materials
Note. Consent for photograph release was provided by the participants.

Figure 2. Study Procedures and Timeline
Note. VR and Tablet-only conditions are experienced for two weeks each, in a counterbalanced order across participants.

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Picture Book
Tablet
VR

Figure 1. Study Conditions and Materials

Note. Consent for photograph release was provided by the participants

508x254mm (300 x 300 DPI)

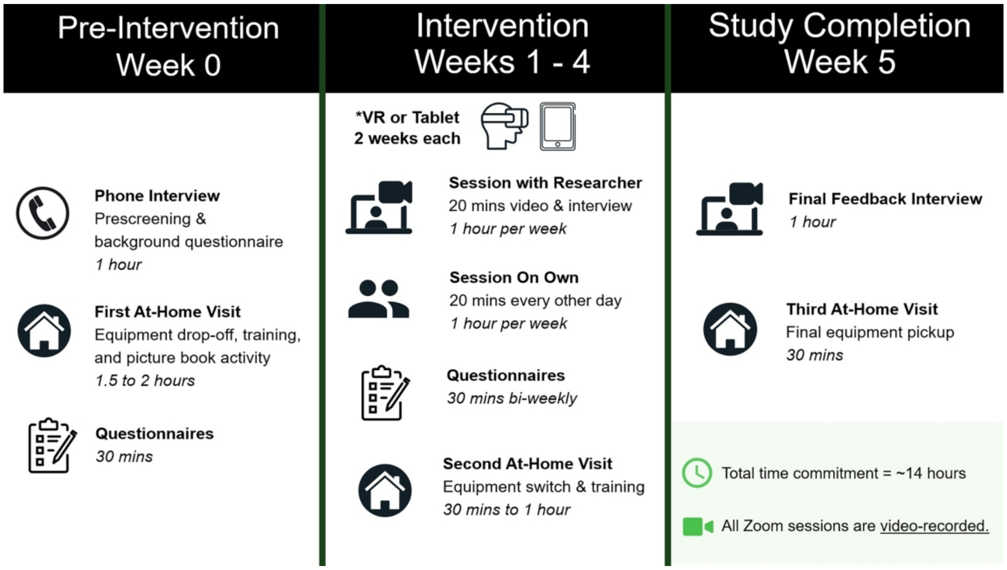

Figure 2. Study Procedures and Timeline

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