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Effect of immersive virtual reality reminiscence versus traditional reminiscence on social well-being among older adults in eldercare centres in Singapore: A randomized controlled trial protocol

Kelvin Cheng Kian TAN PhD[a], Kenny Tan[b], Alan Wong[b], Lee Jinq Yi[b], Ivy Chia PhD[a], Yihong Gan[c]
[a]Singapore University of Social Sciences, Singapore; [b]St Luke's ElderCare Ltd, Singapore; [c]University of Chicago, USA

**Corresponding author: kelvintanck@suss.edu.sg*

Abstract
Background: Singapore's population is rapidly aging. By 2026, the nation will be "super-aged" with over 1 in 5 citizens ≥65 years old, with this ratio increasing to 1 in 4 (approximately 1 million residents) by 2030. Loneliness and social isolation are prevalent among older adults, and are linked to depression, cognitive decline, and poorer physical health. A 2021 survey found nearly 1 in 3 Singapore older persons (aged ≥60) feel lonely most of the time and global statistics indicate an estimated one in four older persons experience loneliness. Reminiscence therapy – the guided recall of past events and experiences – is a popular psychosocial intervention that can improve older adults' well-being. Traditional reminiscence utilizes stimuli like photographs, music, or personal mementos. Emerging technology such as immersive virtual reality (VR) offers a novel medium for reminiscence by vividly recreating places and experiences, potentially enhancing engagement and emotional impact. VR-based reminiscence has shown promise in improving mood, reducing isolation, and stimulating memories in older adults (Syed-Abdul et al., 2019). However, the role of fully immersive VR in reminiscence interventions remains nascent; few rigorous studies have evaluated its effects on healthy older persons' psychosocial outcomes. To date, no structured RCT research in Singapore has examined the use of VR in reminiscence, making this the first local study to do so.
Objective: This protocol aims to evaluate the efficacy of immersive VR reminiscence therapy in enhancing psychosocial well-being among community-dwelling older adults in Singapore, compared to traditional reminiscence using photos/videos. The primary objectives are to evaluate the impact of VR on quality of life, subjective happiness, and loneliness., and to examine older adults' technology acceptance of VR using the Senior Technology Acceptance Model (STAM). A secondary objective aims to explore participants' experiences in the use of VR and any practical or ethical considerations in implementing VR for older persons.
Methods: The study will involve a two-arm randomized controlled trial with 60 older adults (≥60 years) recruited from elder care centers. Participants will be randomly assigned (1:1) to an intervention group (VR reminiscence therapy) or a control group (traditional reminiscence with equivalent content in 2D). Both groups will undergo four weekly reminiscence sessions guided by a trained facilitator, each built around a specific theme and content module. VR sessions will include the use of an immersive headset to present 360° video or virtual environments tailored to reminiscence themes (e.g., visiting a local heritage site or a past travel destination), followed by guided group discussions. Control sessions will involve similar themes and facilitator prompts but use photos, videos or music on a TV/tablet (2D format) instead. Outcome measures will be administered at baseline (pre-intervention) and post-intervention. The key measurements include the Older People's Quality of Life questionnaire (OPQOL-brief) for quality of life, the Subjective Happiness Scale, and the UCLA Loneliness Scale. Technology acceptance will be measured via a 14-item Senior Technology Acceptance Model (STAM) questionnaire adapted for VR (Shin et al., 2023). Additional measures include demographic and health information, and session feedback. All participants will provide informed consent, and ethical approval has been obtained from the institutional review board. Quantitative data will be collected via interviewer-administered surveys, and qualitative observations or interviews will be conducted to capture participants' experiences with the VR intervention.
Results: The primary outcomes (quality of life, happiness, loneliness) and technology acceptance scores will be compared between the VR and control groups after the intervention. We hypothesize that the VR group will show greater improvements in psychosocial well-being than the control group, and that older adults will report high acceptance of the VR technology (e.g. perceiving it as useful and not overly difficult to use). No interim analy-

ses are planned. As this is a protocol paper, the results are not presented at this stage.
Conclusions: This study will inform if immersive VR reminiscence can enhance older adults' well-being beyond conventional reminiscence approaches, and if VR could become a valuable tool for active aging initiatives, reducing loneliness and improving quality of life for older persons in Singapore (Syed-Abdul et al., 2019). The findings will also inform gerontechnology acceptance theory by applying the STAM to immersive VR: identifying factors that facilitate or hinder older persons' adoption of VR for therapy. By outlining detailed session designs and ethical safeguards, this protocol aims to guide safe and meaningful implementation of VR reminiscence in eldercare settings. Ultimately, this pioneering local study can provide evidence to policymakers and practitioners on integrating immersive media into psychosocial care for the aging population and pave the way for larger-scale trials and innovation in reminiscence therapy.

Keywords: virtual reality, reminiscence therapy, older adults, loneliness, quality of life, technology acceptance, Singapore

Introduction

Background and rationale

Singapore faces rapid population aging, bringing urgency to address older adults' mental and social well-being. By 2030, one in four Singaporeans will be 65 or older. Living longer can be accompanied by social isolation – the number of older persons living alone is rising, and nearly one-third of Singapore's elders report frequent loneliness (Malhotra R et.al. 2021). This trend reflects a broader issue: the World Health Organization has identified social isolation and loneliness as widespread problems that seriously affect older people's health, quality of life, and longevity (World Health Organization, n.d.). A recent meta-analysis found that lacking social connections is associated with a 26–32% increased risk of earlier mortality among older adults, an effect comparable to well-established health risk factors (Holt-Lunstad et al., 2015). In response, policymakers and care organizations are promoting "active aging" and developing community-based interventions to support older persons' psychosocial needs.

Reminiscence therapy is a well-established non-pharmacological intervention that involves prompting older adults to recall and share memories from their past. First formally conceptualized by Butler as life review therapy in the 1960s, reminiscence is thought to be a natural adaptive process for older people, helping them derive meaning and resolve conflicts as they age. Reminiscence activities can take many forms – from simple nostalgic conversations to structured life reviews – and can be conducted individually or in groups by professionals or lay facilitators. Numerous studies have demonstrated benefits of reminiscence interventions: they can increase positive mood and life satisfaction, reduce depression and behavioral symptoms in dementia, enhance self-esteem, and improve quality of life in older adults (Xu et al., 2023;Laidlaw et al., 2023).A review by Shin and colleagues found that reminiscence therapy significantly improved quality of life and life satisfaction among community-dwelling older adults without dementia (E. Shin et al., 2023). These psychosocial gains make reminiscence a valuable approach for healthy older persons as well as those with cognitive impairment.

Traditionally, reminiscence therapy relies on sensory cues and personal artifacts to evoke memories. Common media include photographs, letters, familiar music, videos of past events, or cherished objects such as souvenirs and heirlooms. In group settings, participants may share stories prompted by these items, guided by a facilitator. With the advance of technology, digital tools have been incorporated – for instance, displaying slide shows or videos on screens, or using tablets with photo albums. These methods provide visual and auditory stimuli that can spark conversations about the past. However, such conventional media are still relatively passive and may not fully immerse the individual in the experience.

Virtual reality (VR) is an emerging technology that can create fully immersive simulations of real or imagined environments and has gained attention as a tool in gerontology and healthcare for use in stroke rehabilitation to cognitive training. Applying VR to reminiscence is a novel and promising idea: by virtually "transporting" users to specific places or events, VR could trigger richer reminiscences and emotions than viewing 2D images on a screen. For example, a 360° VR video of a historical landmark or a hometown street might make an older person feel as if they are truly revisiting that place, engaging sight, sound, and sense of presence. VR also enables experiences that may be difficult for frail older persons to achieve in real life, such as traveling to faraway destinations or reliving past adventures. In essence, VR-based reminiscence can provide meaningful, engaging activities that spark joy and nostalgia.

Early evidence suggests that immersive VR reminiscence can indeed benefit older adults. A

recent systematic review reported that fully immersive VR reminiscence interventions tend to enhance participant engagement and enjoyment, and can improve mood, reduce anxiety, and even support cognitive function in older users (Ng et al., 2024). Qualitative observations from these studies indicate that seniors often describe VR sessions as enjoyable and exciting, leading to enthusiastic conversations after sessions. Moreover, VR interventions have generally been found usable and acceptable for older persons, with only minor side effects like dizziness reported in a few cases (Ng et al., 2024). An unpublished vendor's report from SilVR Adventures, a provider specialising in VR solutions for older adults, suggests highly positive observations on the use of virtual reality (VR) reminiscence sessions in aged care settings. The company's trials with aged care residents indicated unanimous response, reporting that 100% of participants demonstrated both improved memory recall and heightened conversational engagement immediately following the VR sessions. SilVR Adventures characterizes VR as a powerful therapeutic instrument capable of helping older adults actively recall memories, elevate their mood, and cultivate a deeper sense of connection. Furthermore, the company also mentioned that by immersing participants in meaningful shared experiences, ranging from virtual tours of famous landmarks and wildlife sightings to music concerts, VR effectively fosters social interaction, helps to reduce feelings of isolation, and instills a renewed sense of purpose and connection among older persons. Despite its promise, VR reminiscence therapy is still a nascent field of research. Many VR studies so far have been small pilot trials, often without control groups, and focused on clinical populations like dementia patients (Saredakis et al., 2021). There is a need for more rigorous, controlled studies examining VR's efficacy on psychosocial outcomes in healthy, community-dwelling older adults. Furthermore, local context matters: most VR content is developed overseas, and cultural relevance of the virtual experiences could influence their effectiveness in evoking personal memories. Singapore's multicultural elderly population may have unique preferences for reminiscence themes (e.g. local places, cultural festivals) that differ from Western settings. To our knowledge, no published study has evaluated immersive VR reminiscence therapy among healthy older persons in Singapore. The present study aims to fill this gap by testing an immersive VR reminiscence program co-developed with a community care provider (St Luke's ElderCare Ltd) and customized to older Singaporeans, in comparison with conventional reminiscence therapy using photos/videos (2D media). This project represents the first local initiative to assess the feasibility and benefits of VR for improving elders' well-being.

Another key aspect of introducing any new technology to older adults is technology acceptance. Many promising gerontechnologies fail to achieve widespread adoption because older users find them intimidating, not useful, or not tailored to their needs. The Technology Acceptance Model (TAM) posits that two main factors – perceived usefulness and perceived ease of use – determine an individual's willingness to adopt a new technology (H. R. Shin et al., 2023). However, TAM was developed in general adult populations and may not fully capture older adults' perspectives. Chen and Chan proposed the Senior Technology Acceptance Model (STAM) to account for additional factors relevant to elders, including age-related physical/cognitive abilities, health status, gerontechnology anxiety (discomfort or fear of new tech), and attitudes toward aging (H. R. Shin et al., 2023). STAM suggests that an elder's acceptance of a technology is influenced not only by usefulness and ease of use, but also by their health constraints, self-efficacy, and life satisfaction. A shortened 14-item STAM-based questionnaire has been validated to measure these dimensions efficiently (H. R. Shin et al., 2023). Applying STAM in this study will allow us to systematically gauge how older Singaporeans perceive immersive VR – Do they find it beneficial for them? Is it easy or intimidating to use? – and what factors might facilitate or hinder their acceptance. Understanding acceptance is critical for implementation: even if VR reminiscence is effective, it can only make an impact if older persons are willing and able to use it. This study will therefore integrate an acceptance assessment alongside outcome measures to inform strategies for technology adoption in eldercare.

Study objectives

In summary, the study addresses two broad questions:

1. Efficacy of VR Reminiscence: Does immersive virtual reality reminiscence therapy lead to improved psychosocial well-being in older adults, compared to traditional reminiscence using 2D media? We hypothesize that participants receiving VR will show greater improvements in key outcomes – including quality of life, happiness, and loneliness – than those receiving conventional reminiscence. This will be evaluated through pre-post changes in standardized measures between the two groups.

2. Technology Acceptance: How do older adults accept and experience the immersive VR technology used for reminiscence? We will use the

Senior Technology Acceptance Model to measure factors such as perceived usefulness of VR for reminiscence, perceived ease of use, gerontechnology anxiety, and overall satisfaction. We aim to identify any facilitators or barriers to VR acceptance among older persons. Additionally, we will qualitatively explore participants' experiences during the VR sessions (e.g. comfort, emotional reactions, memory triggers) to complement the quantitative acceptance data.

By achieving these objectives, the study seeks to provide evidence on whether VR can be an effective and acceptable intervention for promoting mental and social well-being in Singapore's aging population. The ultimate goal is to inform future larger-scale implementations and guide best practices (e.g. content design, facilitator training, ethical safeguards) for using immersive VR in community eldercare settings.

Methodology

Study design

This research will employ a randomized controlled trial (RCT) with a mixed-methods evaluation. The quantitative component is a two-arm RCT comparing an experimental group receiving immersive VR reminiscence therapy to a control group receiving traditional reminiscence therapy. Participants will be randomized in a 1:1 ratio to the two groups after baseline assessment. Block randomization will be used to ensure equal group sizes, and stratification by age band (e.g. 60s vs ≥70s) will be considered to balance age-related factors. Due to the nature of the intervention, blinding of participants and facilitators is not feasible – participants will know whether they are using a VR headset or not. However, outcome assessors (research staff administering post-intervention surveys) will be independent and, as far as possible, blinded to group allocation.

The RCT is designed to establish causal efficacy of the VR intervention, tested against usual traditional reminiscence as the control condition . The study is parallel-group (no crossover) and will last approximately 6–8 weeks in total for each participant (including baseline, 4 weeks of sessions, and post-test). In addition to quantitative outcome measures, we will incorporate qualitative observations and interviews for a more holistic evaluation. This multimethod approach echoes prior gerontechnology studies, enabling us to triangulate survey results with real-life experiences (Tan et al., 2023). The study protocol has been developed in accordance with APA style and ethics guidelines, and is modeled after a similar successful gerontechnology trial (examining a social robot intervention) conducted in Hong Kong and Singapore.

Ethical approval and considerations

This study has obtained ethical approval from the Institutional Review Board of the Singapore University of Social Sciences (Approval HBR-0005-2023-FUL-02). In addition, we have secured collaboration agreements and site permissions with St Luke's ElderCare (SLEC), the community partner from which participants will be recruited and the intervention delivered. All participants will provide written informed consent prior to enrollment. The consent process includes a clear explanation of the study purpose, procedures, potential risks and benefits, and the voluntary nature of participation. Participants will be assured that they may withdraw from the study at any time without penalty and without affecting their access to services.

Several ethical considerations specific to working with older adults and VR technology have been addressed:

Participant Safety: VR can cause mild side effects such as dizziness or disorientation in some users. To mitigate this, all VR sessions will be conducted with participants seated in a stable chair. A researcher or facilitator will remain nearby to ensure safety (e.g., preventing falls or removing the headset if a participant feels unwell). Before the first VR session, participants will be oriented on how to use the headset and what to expect, to reduce anxiety. We will exclude any individuals with known severe vestibular disorders or epilepsy that could be triggered by VR visuals.

Emotional Well-being: Reminiscence can sometimes evoke unpleasant memories or sadness, for example reminiscing about deceased loved ones might trigger grief. One prior study noted that VR content triggered adverse feelings in some participants by surfacing painful memories (Lu et al., 2023). Our facilitators will be trained to handle emotional reactions with empathy. If a participant becomes distressed during a session, the session will be paused or stopped, and emotional support will be provided. If required, referral to counseling will be provided, though serious distress is not anticipated given our focus on positive reminiscence. Content for VR and discussions is curated to emphasize positive, affirming memories (see Session Design below) in order to minimize potential harm. Nonetheless, participants are free to skip any question or to decline continuing a session if they feel uncomfortable.

Privacy and Confidentiality: During group reminiscence discussions, participants may share personal stories. All participants will be reminded to respect each other's confidentiality. The sessions will not be video- or audio-recorded (to encourage open sharing). Any notes taken by research-

ers (for qualitative observations) will use pseudonyms. Survey data and consent forms will be stored securely in locked cabinets or password-protected databases at SUSS. Only the research team will have access to identifiable information, and data will be reported only in aggregate or with anonymized quotes.

No Conflict of Interest: The content library is embedded in the VR solution provided in-kind by SilVR Adventures, but they have no role in study design, data analysis, or result dissemination. This independence is clearly stated to participants.

Overall, the design prioritizes participants' safety, dignity, and autonomy throughout the process.

Participants and recruitment

Community-dwelling older adults from Singapore, primarily through SLEC's network of eldercare centers and outreach programs. The inclusion criteria are: (1) age 60 years or above; (2) able to communicate in either English or Mandarin (to participate in discussions and understand instructions); (3) cognitively intact or only mild cognitive impairment (screened via self-reported history or a Montreal Cognitive Assessment cognitive test if needed) – individuals with diagnosed dementia will not be included, since our focus is on healthy older persons; (4) no severe visual, hearing, or mobility impairments that would preclude using VR equipment or attending sessions; and (5) provides informed consent and is willing to be randomized to either intervention or control.

Exclusion criteria include: (1) presence of uncontrolled epilepsy or other neurological conditions that could cause VR to be unsafe; (2) severe motion sickness susceptibility; (3) major psychiatric conditions (untreated depression, psychosis) that could interfere with participation; and (4) inability to attend the weekly sessions consistently (e.g. due to travel or health issues). (5) We will also exclude those living in nursing homes or requiring institutional care, as the intervention is designed for community settings.

Recruitment procedure: SLEC staff will assist in identifying potential participants among their clients. Study brochures and presentations will be delivered at five eldercare centers to introduce the project. Interested individuals (or their family members) can contact the research team or give permission for us to contact them. Snowball sampling will be used, with participants referring friends. This sample size was recommended based on feasibility and reference to similar pilot trials – for instance, an RCT in Taiwan examining VR effects on older persons' well-being had 60 participants and reported significant gains in happiness for the VR group (Barsasella et al., 2020). Although a formal sample size calculation was challenging due to limited existing effect size data for VR, a sample of ~60 should provide sufficient power to detect medium effect sizes ($d \sim 0.6$) with $\alpha = 0.05$ and power 0.8 in between-group comparisons (Barsasella et al., 2020).

Once individuals express interest, a screening session will be arranged. Research staff will verify eligibility, explain the study in detail, and obtain written consent. Baseline data collection (pre-intervention questionnaire, see Measures Section) will then be scheduled. Only after completing baseline measures will participants be randomized to VR or control group, to prevent any pre-intervention bias. Each participant will be assigned a unique ID code, and group allocation will be concealed in an opaque, sequentially numbered, tamper-proof envelope (CONSORT standard) opened by an independent coordinator.

Retention strategies: We anticipate high adherence by integrating the intervention into enjoyable group activities at the eldercare centers. Nevertheless, to minimize dropouts, we will provide reminder calls before each session and arrange transport for participants with mobility difficulties if needed. If a participant misses a session, we will attempt a make-up session within the same week. Tokens of appreciation (e.g. gift voucher) will be given upon study completion to acknowledge their time and effort.

Intervention: VR reminiscence therapy vs. traditional reminiscence

Participants in both groups will engage in four reminiscence sessions over four consecutive weeks, approximately one session per week. Each session is expected to last 60 minutes, including preparation and debriefing. To maintain consistency, sessions for both conditions will follow the same structure and themes, differing only in the medium of reminiscence stimuli (immersive VR vs. non-immersive 2D materials).

Sessions will be conducted in small groups of 5 participants per session, facilitated by a trained reminiscence facilitator (either a therapist or social worker) with the assistance of a researcher for technical support. Group sessions are chosen to leverage social interaction – sharing memories in a group can enhance engagement and peer support (Elias et al., 2015). If group composition varies in language comfort, separate groups will be formed as needed.

VR reminiscence therapy (intervention group)
Participants assigned to the VR group will use an immersive VR headset (e.g., Oculus Quest or similar standalone device) to experience custom-selected virtual environments aligned with reminiscence themes. Four VR content modules will be available, each corresponding to a specific reminiscence theme common in life-review frameworks (focusing on positive memories). The modules and session design are as follows:

Session 1: Travel around the World. VR Module: An immersive travel adventure – participants will virtually visit a famous landmark or a scenic destination, such as the Eiffel Tower in Paris, the Great Wall of China, or a serene beach sunset. This module is typically very engaging, as many older persons have places they dreamed of visiting. VR allows them to experience those environments visually. If possible, we will choose a location that at least one group member has visited before to prompt sharing. Facilitator Guide: After the VR tour, discussion questions: "Have you ever traveled to this or a similar place? What was your experience?"; "What is a place you always wanted to visit but never had the chance?"; "What kind of trips or leisure activities did you enjoy when you were younger?" This closing session encourages sharing of joyful memories (honeymoons, family vacations, hobbies) and also future-oriented thinking (it's not too late to fulfill certain desires virtually or locally). It often ends on an uplifting note of collective enjoyment of the VR journey.

Session 2: Exploring Singapore. VR Module: A virtual visit to popular places in Singapore: Gardens by the Bay, Marina Bay, Sentosa, Chinatown and Merlion. For example, a 360° VR film of the familiar places in Singapore. VR content is a virtual tour or a montage of Singapore's landscape evolving (to symbolize developments and trends). Bring the bustling to the tourist spots, followed by entering the botanical environment. Facilitator guide: "Did you go to places like the ones in the video – what memories do you have of those trips?" Participants will reminisce about family gatherings, traditional foods, roles they played at home, etc. Sharing these memories can reinforce feelings of belonging and identity to the places. For many in this age group, a common experience was Singapore's developing economy in the 70s–80s.

Session 3: Festivities VR Module: A VR scenario showcasing a festivities like New Year countdown, Chinese New Year and Christmas in the community and public places setting relevant to the cohort. This module provides rich cues of family life – sights, sounds and culturally significant details. Facilitator Guide: Discussion questions include: "What did your family's home look like when you were raising your children or growing up?"; "What were your favorite family traditions?". We will tailor this to participants' backgrounds as much as possible.

Session 4: Animals and Safari Tour. VR Module: A 360° virtual recreation of nature and animals. During the early nation building days, we have more farm places. In the lives of our older persons, they are familiar with pets. Participants will be virtually "placed" in a nostalgic environment with the wonder of nature. Facilitator Guide: After the VR experience (~5 minutes), the facilitator will prompt discussion: "How was your living environment similar or different to what you just saw?"; "What animals did you enjoy when you were a child?"; "Do you recall an animal who made those days special?" The goal is to evoke early childhood memories and positive feelings of youth. Participants are encouraged to share stories about their schooling, friendships, and connections with animals.

Throughout all VR sessions, the facilitator's role is to ensure each participant is comfortable with the technology and to guide reflection after the VR exposure. VR exposure per session will be kept moderate – roughly 5–10 minutes of VR content – to avoid fatigue or sensory overload. Participants will take turns if there are fewer headsets than people, or ideally all simultaneously if devices are available for each. When one is using VR, the carers can watch the 2D view on a monitor (the VR feed can be cast to a TV), so they also see what is happening and feel involved. This helps seed the group discussion as everyone witnesses the content.

After each VR viewing, the headset is removed and participants are given a few moments to readjust (have a sip of water, etc.). Then the group discussion proceeds for about 20–30 minutes using the guide questions. The facilitator uses gentle probing and validation techniques learnt from reminiscence therapy training – e.g., asking follow-ups, drawing out quieter members, linking someone's story to another's if appropriate. A research observer will take notes on notable reactions (smiles, tears, specific comments like "It felt so real!") for qualitative analysis, but will not intrude. Sessions end with the facilitator summarizing and thanking participants for sharing their memories.

Traditional reminiscence therapy (control group)
The control group will undergo reminiscence sessions that are identical in themes, schedule, and facilitator involvement – the only difference is the absence of VR immersion. Instead of us-

ing VR headsets, this group will use conventional materials corresponding to each module:

- Session 1: Travel around the World. The facilitator will show photographs or a short video clip of popular places around the world. These visuals will be printed on cards or displayed on a laptop or projector for the group to view. For this session 1, the discussion prompts are the same ("Tell us about places you visited…"), focusing on eliciting the memories without the immersive element.

- Session 2: Exploring Singapore, we will prepare photos or printed news clippings highlighting workplaces of the past or community events (e.g Gardens by the Bay, Marina Bay, Sentoa, Chinatown and Merlion – depending on participants' backgrounds gathered at baseline). The facilitator might also use prompt objects like a vintage tool or item from past occupations. Discussion covers proud achievements in sync with the development of Singapore, similar to VR group. This session elicit reminiscences that affirm the elder's sense of accomplishment and purpose, reinforcing positive self-concept.

- Session 3: Festivities, the control stimuli include old photos or video snippets of a 1970s, New Year countdown, Chinese New Year and Christmas in the community and public places. Facilitator will guide the same conversation about home life and traditions.

- Session 4: Animals and Safari Tour, participants will view photographs or a conventional video of the chosen environment (for example, farm places, Night Safari). Though not immersive, it provides visual context. The group can pass around any related keepsakes (one participant who have a pet before can show photos). They then discuss their memories of connections with animals. Similar questions as the VR group can be used.

In each control session, the duration and format mirror the VR sessions: about 10 minutes of viewing stimuli (photos/videos) followed by 20–30 minutes of group reminiscence sharing. The facilitator's training and guides are the same, emphasizing positive recollections and group engagement.

By keeping content themes and discussion identical across groups, we ensure the primary difference is the delivery medium (immersive VR vs. 2D). This controls for the social interaction and facilitator effects – both groups receive equal attention and similar conversational therapy. Any difference in outcomes can thus be more confidently attributed to the immersive experience provided by VR.

All sessions for both groups will take place in a private activity room at the eldercare center, at a regular morning time (when participants are alert). The environment will be quiet and free of hazards, with chairs arranged in a semi-circle (and ample space for a facilitator to assist with VR equipment in the intervention group). The room setup and group size are kept consistent between conditions.

Facilitator training: Facilitators are experienced in eldercare and have undergone a workshop on reminiscence therapy principles. In addition, those leading VR sessions receive an orientation to the VR device operation and troubleshooting. They also learn how to introduce VR gently to first-timers (e.g., reassuring them and demonstrating on themselves first). A written facilitator guide with session-by-session outlines and suggested questions (as exemplified above) will be provided to maintain consistency. The facilitators will also fill out a brief checklist after each session noting whether key topics were covered and any notable issues (like a participant not engaging or any technical difficulty).

Fidelity monitoring: Researchers will rotate observing sessions (without actively participating) to ensure the protocol is followed. Any deviations or incidents will be documented. For instance, if a VR headset malfunctions and a session has to be altered, that will be recorded and addressed (possibly by rescheduling that session for that group). Such notes ensure that both arms have comparable exposure and that the intervention delivered matches the protocol.

Outcome measures

Multiple standardized instruments will be used to evaluate the impact of the intervention on participants' psychosocial outcomes and to assess technology acceptance. Unless otherwise noted, all instruments have been previously validated in older adult populations, and where available, we use versions or translations suitable for Singapore's cultural context. Trained bilingual researchers will administer the questionnaires in the participants' preferred language (English or Mandarin). For any scales not available in Mandarin, we will translate and back-translate them to ensure accuracy.

Based on the literature review conducted, the key measures recommended include:

- Older People's Quality of Life (OPQOL-Brief): Quality of life will be measured using the brief Older People's Quality of Life questionnaire. The OPQOL-Brief is a 13-item self-report scale derived from the original 35-item OPQOL, which

was developed specifically from older adults' perspectives. It covers various domains such as health, social relationships, independence, financial circumstances, and life purpose. Participants rate items on a Likert-type scale (e.g. strongly agree to strongly disagree) regarding their satisfaction with life aspects. The OPQOL-Brief has shown good psychometric properties (reliability and validity) as a concise QoL measure for older persons (Bowling et al., 2012). Higher scores indicate better quality of life. This instrument was chosen because it is tailored to older populations and sensitive to changes in psychosocial well-being.

- Loneliness (UCLA Loneliness Scale): We will assess subjective loneliness using the UCLA Loneliness Scale Version 3. This is a widely used 20-item questionnaire where respondents indicate how often they feel lacking companionship, left out, or isolated (e.g., "How often do you feel alone?") on a 4-point scale ("Never" to "Often"). It has high internal consistency and validity for measuring the subjective feeling of social isolation (Russell, 1996). We anticipate that engaging in group reminiscence (especially VR-augmented) may reduce feelings of loneliness, as it fosters social connection and meaningful interaction. A decrease in UCLA score from pre-intervention to post-intervention would indicate reduced loneliness.

- Subjective Happiness Scale (SHS): The SHS is a brief measure of global subjective happiness developed by Lyubomirsky and Lepper. It consists of 4 items; two items ask respondents to characterize themselves using 7-point Likert scales (e.g., "In general, I consider myself: 1 = not a very happy person … 7 = a very happy person"), and two other items present descriptions and ask the extent to which each description applies (e.g., rating happiness relative to peers). The SHS has demonstrated good reliability and construct validity (Lyubomirsky & Lepper, 1999). It is included to capture any improvement in overall happiness or life satisfaction that might result from participating in enjoyable reminiscence sessions. Scores range from 1 to 7, with higher scores indicating greater happiness.

- Technology Acceptance (Senior Technology Acceptance Model Questionnaire): To evaluate how participants view the VR technology, we will use a shortened STAM-based questionnaire adapted from Chen and Lou's 14-item scale (Chen & Lou, 2020). This instrument measures several components: perceived usefulness of the technology (e.g., "Using VR can improve my quality of life"); perceived ease of use (e.g., "VR is easy to learn and operate"); gerontechnology anxiety (e.g., "I feel nervous or anxious using new electronic devices" – reverse scored for positive attitude); perceived control and facilitating conditions (e.g., "I have the resources and knowledge to use VR if I want"); and health and ability considerations (e.g., "My health conditions allow me to use VR technology comfortably"). Each item will be rated on a 10-point Likert scale from 0 (strongly disagree/very difficult/etc.) to 10 (strongly agree/very easy/etc.), as was done in prior studies. We will instruct the participants in the VR group to answer specifically with regard to the VR reminiscence system they used (the headset and software), phrasing items accordingly (e.g., "The VR reminiscence system was easy to use"). For the control group, the STAM measure is not applicable since they did not use VR; this measure is not needed for control group; only comparison within the VR group against neutral benchmarks is required. The STAM questionnaire has been shown to explain a large proportion of variance (over 80%) in older adults' technology usage when tailored to a specific device (Chen & Lou, 2020). A higher overall score will indicate greater acceptance and likelihood of adopting VR if available in the future. We will examine which subscales (e.g., usefulness, ease of use) are most strongly rated, to understand what drives acceptance.

- Engagement and Session Feedback: Although not a standardized scale, it will collect participant feedback after each session in a brief form. This includes a rating of how much they enjoyed the session (e.g., 5-point smiley face scale from very unenjoyable to very enjoyable), and an open-ended question "What did you like or not like about today's session?" In the VR group, additional questions like "Did you experience any discomfort while using VR (e.g., dizziness)?" will be asked to monitor side effects. These feedback forms serve both as a process evaluation and to ensure participant well-being. They are not primary outcomes but will inform the interpretation of the results (for instance, if someone did not benefit, was it because they felt nauseated by VR?).

- Demographics and Background: At baseline, we will record age, gender, ethnicity, education level, living situation (alone or with family), and prior experience with technology (smartphone use, gaming, etc.). We will also note if they have any prior familiarity with VR (expected to be minimal in this cohort). Basic health information (self-rated health, vision/hearing status, mobility, any diagnosed conditions) will be collected to characterize the sample and check for any confounding variables. For example, if VR group had more frail participants, we would need to account for that in analysis.

All quantitative measures (OPQOL, UCLA, SHS, STAM) will be administered at two time points: pre-intervention (baseline), typically within one week before the first session, and post-intervention, within one week after the final session. The baseline administration helps establish each participant's starting level on outcomes and allows us to measure change over the course of the intervention.

It is important to ensure measures are administered in a consistent manner. The questionnaires will be interviewer-administered one-on-one in a quiet room, to avoid issues with literacy or vision (the researcher reads questions aloud and records answers). Each session of data collection takes about 30–40 minutes. To reduce respondent burden, short versions of scales (OPQOL-Brief, SHS, etc.) were intentionally selected. Participants can take breaks during the survey if needed.

For qualitative insights, we will also conduct a post-intervention focus group or individual interviews with a subset of participants from the VR group (and possibly the control group for comparison) to gather in-depth feedback on their experiences. An interview guide will cover questions like "How did you feel about using VR for reminiscence? What was the experience like for you?", "Can you describe any memories or feelings that the VR sessions brought up?", "Would you want to do something like this again, and would you recommend it to friends?" and "How did the VR sessions compare to other activities you normally do at the center?". We anticipate that 15–20 participants can be interviewed, and their perspectives will complement the quantitative acceptance data.

Procedure for data collection

Baseline Assessment: After consent, participants will be scheduled for a baseline assessment session approximately 1 week prior to starting the reminiscence sessions. During baseline, the researcher will administer the questionnaire battery (demographics, OPQOL-Brief, UCLA Loneliness, SHS, and for those assigned to VR, the STAM can technically only be fully answered before and after experiencing VR, so STAM will be administered pre/post-intervention for VR group). The baseline loneliness, happiness, and QoL scores will serve as covariates to compare changes.

Randomization: Once baseline data is collected, participants will be randomly assigned to either the VR reminiscence group or the control group. They will then be informed which program they will participate in. Group sessions will be scheduled, often grouping participants by availability and language. For example, we might have a "VR Group A" of 5 people meeting in the morning and a "Control Group B" of 5 people meeting another morning, etc., until all participants complete four sessions. Sessions will likely be spread over multiple cycles if we have more than one group per arm (given 30 per arm, we might form 5 groups of ~6 in each arm). This rolling enrollment will continue until the target sample is completed.

Intervention Period (Week 1–4): Participants attend the weekly reminiscence sessions according to their group assignment (as detailed in the Intervention section above). A log will be kept for attendance and any deviations. If a participant in the VR group misses a session, he would still receive the VR exposure and the team will attempt to arrange for him to join a group sharing in a makeup group. Similarly for control, we provide a catch-up with materials if possible. However, if someone misses more than two sessions, we may consider them a dropout for efficacy analysis, though still include them in intention-to-treat analyses by carrying baseline measures forward.

Post-Intervention Assessment: Within one week after the final (4th) session, participants will be re-administered the outcome measures. This post-test survey will include OPQOL-Brief, UCLA Loneliness, SHS again. Additionally, now that the VR group has experienced the technology, we will administer the STAM questionnaire to the VR group in full at this point (asking them to reflect on the VR they used).

An independent researcher not involved in earlier sessions will conduct post-intervention surveys to minimize bias and reassure participants that honest responses are valued.

Qualitative Interviews: Shortly after post-surveys, focus groups or interviews will be arranged with those who agreed. These will be audio-recorded (with permission) and transcribed for analysis. They are exploratory and aimed at enriching our understanding; thus they are not mandatory for all participants.

Data Management: Each participant's data from baseline and post will be matched by their unique ID. Data will be entered into a secure database. We will double-enter a subset to ensure accuracy. Identifying information will be stored separately from survey responses. All hard copy forms will be stored in locked file cabinets accessible only to the research team. After the study completion, data will be retained for at least 5 years as per guidelines, then securely destroyed.

No interim analyses or stopping rules are predefined, given this is a relatively short and low-risk intervention. However, the research team will monitor for any adverse events. If any serious adverse event related to the study occurs (e.g., a participant injury or hospitalization potentially related to the sessions), it will be reported to the IRB immediately and the study could be paused for review.

Note: In this protocol, we do not detail the statistical analysis plan per se (in keeping with not including results or analysis), but in practice we will compare pre-post changes between groups using appropriate statistical tests (e.g., ANCOVA controlling for baseline) and analyze acceptance descriptively. The focus here is on the design and methodology of how data will be collected to answer our research questions.

Discussion and conclusion

This study will systematically examine the use of immersive virtual reality as a tool for reminiscence therapy among older adults in Singapore. By comparing VR-enhanced reminiscence with a traditional reminiscence approach, we aim to isolate the added value of immersion and presence that VR can provide. At the individual level, we expect the VR reminiscence experience to produce greater psychosocial benefits – participants may report feeling happier and more socially connected, with a renewed sense of vitality from "traveling" and engaging in novel experiences. We expect the loneliness scores will decrease more in the VR group if the shared immersive experiences successfully foster camaraderie and conversation, addressing the loneliness epidemic in a fun, meaningful way (Margrett et al., 2022). An improvement in quality of life and mood in the VR group, if observed, would align with prior findings that VR interventions can positively influence well-being and mental health in older persons (Ng et al., 2024).

Importantly, even if both VR and traditional reminiscence improve outcomes (which is possible, since any social activity and reminiscence can be beneficial), this study will tell us if VR provides an added boost beyond the conventional method.

At the community and societal level, the findings will have implications for how eldercare organizations might integrate technology to combat social isolation. If VR reminiscence is shown to be effective and well-received, eldercare centers and nursing homes could adopt similar programs to enrich their activity offerings. This aligns with Singapore's drive towards a tech-enabled aging sector, where innovations are leveraged to improve older persons' quality of life. For example, success in this study could lead to scaling up VR reminiscence sessions across multiple senior centers, training volunteers to run them, or even implementing intergenerational VR activities (where youth and elders explore VR together, which could further reduce age gaps). The study's collaboration between an academic institution (SUSS) and a service provider (SLEC) exemplifies how research can directly inform practice, contributing to evidence-based interventions in community care.

From a gerontechnology research perspective, our integration of the Senior Technology Acceptance Model will yield insights on the adoption of VR among older adults. If the results show high acceptance (for instance, older persons rating VR as useful for reminiscence and reasonably easy to use), it counters stereotypes that older people are technophobic. Prior work on gerontechnology acceptance (Chen & Chan, 2014) suggests that including age-related factors (e.g. health, anxiety) can substantially improve our ability to predict technology use in this demographic. Our findings may extend the STAM framework and help technology developers to better cater to older end-users. For example, if we find specific barriers - e.g., some participants enjoyed the content but found the headset uncomfortable or had anxiety initially – these can guide improvements in design and implementation. We might learn that certain subgroups (perhaps the "young-old" 60-70 vs "old-old" 80+) have different levels of comfort with VR, or that physical factors (like having to remove spectacles to wear the headset) affect the experience. These findings can extend the STAM framework and help gerontechnology developers to better cater to older end-users. Understanding these factors is crucial for wider adoption: implementation success depends on user acceptance, irrespective of potential efficacy.

The study also pays attention to ethical and practical considerations in deploying VR with older persons. Our protocol includes measures for safety and emotional well-being, which if proven effective (e.g., minimal adverse effects observed), will reassure stakeholders that VR can be used responsibly in this population. Conversely, if certain content triggered negative emotions for some (despite our precautions), that will be an important lesson on content curation – for instance, we might recommend avoiding war-related reminiscence content or tailoring to individual life histories to prevent trauma triggers. By documenting the session guides and facilitation techniques, we provide a template that others can follow or adapt. The facilitator guide

ensures the technology is not used in isolation but embedded in a supportive human context, which is key for any therapeutic use of VR.

There are some limitations to note in this protocol. The sample size, while adequate for a pilot efficacy trial, may limit generalizability and the ability to detect smaller effects. The participants are relatively healthy community-dwelling older persons; results might differ in more frail or institutionalized elderly. Additionally, because the intervention involves group interaction, it is not possible to blind participants to the condition, which could introduce some expectancy bias (for example, some may find VR novel and exciting which itself could boost mood). We attempt to mitigate this by ensuring the control group also has engaging activities, so neither feels at a disadvantage. Another consideration is the novelty effect of VR – participants' enthusiasm might partially stem from doing something new, which could wear off over a longer period. Our study is short-term; future research could examine longer-term outcomes and whether ongoing VR use maintains benefits or yields further improvements (or possibly, diminishing returns).

Despite these considerations, this study is a critical first step in evaluating VR reminiscence in our local context. It leverages a rigorous design and validated measures to produce credible evidence. If our hypotheses hold true, we anticipate finding that immersive VR reminiscence therapy significantly improves older adults' subjective well-being and reduces loneliness compared to traditional methods, while being accepted by the majority of participants. This would be a powerful message to aged care practitioners and policymakers: that investing in new technologies like VR is not just a gimmick but can have tangible benefits for elders' mental health and social engagement.

In conclusion, the presented protocol outlines a comprehensive approach to studying an innovative gerontechnology intervention. We anticipate that by the end of the study (expected in late 2025), we will have data to answer whether VR can indeed enrich reminiscence therapy outcomes and how older Singaporeans respond to this mode of therapy. At an individual level, a successful outcome means happier older persons who feel less alone – an immeasurable gain in quality of life. At a community level, it illustrates how a traditionally low-tech activity like reminiscence can be transformed through innovation to deliver greater impact, informing service development in senior centers nationwide. Finally, at the academic level, this study will contribute to the growing literature on immersive technologies for aging, helping to chart best practices in design and ethical implementation. We hope this work will encourage further interdisciplinary efforts to harness technology in addressing the "loneliness epidemic" and promoting active, joyful aging in Singapore and beyond.

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Conflicts of Interest
The authors declare no conflict of interest.

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