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Feasibility and Usability of an Occupation-Based Immersive Virtual Reality Protocol for Older Adults

Sara Benham [1,*], Alexis Cruz [1], Ashley Oliva [1], Franz Osol [1], Elizabeth Strona [1], Stephanie Kolakowsky-Hayner [2] and Ann Marie Potter [1]

[1] School of Rehabilitation Sciences, Moravian University, Bethlehem, PA 18018, USA; pottera@moravian.edu (A.M.P.)
[2] Good Shepherd Research, Good Shepherd Rehabilitation, Allentown, PA 18103, USA
* Correspondence: benhams@moravian.edu

Abstract: The growing population of aging adults, coupled with the widespread adoption of technology, including within virtual environments, prompts the need to understand technology engagement preferences among older adults. This study aimed to explore the experiences and perceptions of older adults engaging with a client-centered immersive virtual reality (IVR) protocol tailored to their specific occupational interests. Employing a mixed methods approach, the research combined the quantitative System Usability Scale (SUS) assessment with qualitative interviews to examine the feasibility, usability, and learning experiences of community-dwelling older adults. Fifteen (n = 15) older adult participants trialed an IVR session tailored to match their chosen occupations of importance. Findings revealed that the usability of IVR varied significantly among participants, with an average SUS score of 55, indicating a need for further investigation into usability issues. Qualitative analysis identified three themes: IVR is usable when it is intuitive and with training, balance the apps for success, and overall lasting impressions were related to the perceived implementation for the participant. The incorporation of meaningful occupations in IVR programming is feasible and can be integrated into healthy aging-in-place programming; however, expanding available leisure-based apps and increasing the learning time before engagement should be considered.

Keywords: virtual reality; older adults; occupational engagement

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1. Introduction

The older adult population is expected to continue to increase to an estimated 25% of the total US population by 2060 [1]. Older adults, ages 65 and older, are at risk of functional performance declines associated with aging, but recent advancements provide guidance to plan for healthy aging, defined as the individual's self-perceived health and functional abilities, well-being, and life satisfaction regarding aging [2–4]. Previous literature suggests that meaningful, novel activities, as well as reminiscing, may counter aging-related cognitive and psychological declines to promote quality of life [5–7]. Technology advancements may potentially support healthy aging [8]. Older adults maintain currency with their community and engage with others through technology, offering a gateway to discover and pursue personal interests, potentially igniting feelings of purpose [9,10]. Purposeful engagement in technologies may yield benefits; however, the acceptance, quality of user experience, and trust and adoption, should be considered through technical support offerings to address the potential challenges [11–13]. Technology advancements include the integration of immersive virtual reality (IVR) for older adults, which involves the use of a head-mounted device (HMD) to provide a fully immersive experience to view, interact with, and provide a sense of presence in a virtual environment [14]. The recommendation for older adult engagement with IVR includes sufficient safety screening and monitoring to provide multi-modal sensory stimuli of visual, auditory, and tactile inputs [14–16].

IVR research has found the potential of collaboration between caregivers and the elderly seeking to improve individuals' QOL through education in a simulated yet safe environment [15,17] and specifically within physical, cognitive, psychological, and social well-being domains [15]. Engagement recommendations for the older adult to feel that the content is purposeful includes that the experiences should be tailored to their interests, for example, providing virtual visitations simulating social interactions or traveling to new places, or experiences related to educational interests [14]. To foster confidence and acceptability for the varying needs of older adults, IVR programming should consider how the application may be adjusted for capabilities and tailored for personalization [16,18]. For example, applications (apps) may be implemented to promote learning through adaptive backgrounds, realism, interaction, or narrative components [8]. Multiple studies have examined IVR leisure activities to promote improvements in mood and socialization [19–21]. In consideration of the practicalities of setup for leisure engagement, choosing an environment of familiarity is beneficial to pique the interests of the patient and ease interactions during sessions [22,23]. Furthermore, the feasibility examinations of IVR technologies are necessary to understand the restrictions of IVR use for older adults, to then improve QOL and our understanding of older adults' perceived practicalities of program designs [24]. Feasibility is a broad concept, and recommendations include multiple focus areas to be examined intentionally through acceptability, practicality, and implementation proposed programs [25].

IVR safety protocols have been trialed and reported tracking cybersickness, pain, falls, and the overall satisfaction of participants [26]. Older adults may be more susceptible to experience simulator sickness symptoms due to age-related changes in sensory processing and vestibular function, and as tested through previous studies, screening procedures for participation should exclude older adults with significant risk factors for adverse effects, such as cardiovascular issues or a history of motion sickness, while closely monitoring the participant [14,18]. In addition to specific studies that used IVR to assess health outcomes, IVR was considered feasible and beneficial for the older adult population, including for those with underlying dementia, when treating physical, mental, and psychosocial health [27,28]. Previous studies have focused on specific tasks that were feasible for older adults but were not necessarily personalized or relevant to connect to meaning in their lives [22,26,29]. Older adults can participate in valued occupations, in other words, meaningful activity engagement, to experience benefits when presented with an IVR program that is personalized and exciting to them [30]. While recent studies have addressed IVR feasibility with older adults and various IVR apps, there is still limited research regarding the decision-making regarding apps for client-centered and occupation-based IVR engagement. Furthering the preliminary feasibility of IVR and the emphasis on preferred, meaningful engagement for older adults, further research is warranted to investigate the feasibility of a novel, occupation-based IVR protocol to promote learning and productive aging in older adults. This study aimed to provide insight into the learning experiences of older adults during IVR and their perceptions of an IVR protocol when it is client-centered and relevant to them.

This study explored the older adults' perceptions of an IVR protocol experience and determined if participants' preferred engagement within the apps was feasible and tailored to their specific occupational interests. The research question was as follows: what is the feasibility, including usability, learning experiences, and perceptions, of the implementation of matching immersive virtual reality (IVR) apps to their preferred, meaningful occupations for community-dwelling older adults?

2. Materials and Methods

2.1. Research Design

This study employed a mixed methods approach, sequentially through a quantitative strand of a usability measure, then ranking the usability to systematically analyze the qualitative strand component, which delved into participants' lived experiences of the phenomenon experienced with the IVR apps and the system, through content analysis of the interview transcripts. A multidimensional approach to evaluate the usability of IVR is commonly used and preferred to gain the experiential perspectives of participants through the validation, interpretation, and corroboration of data [18,30]. Based on the COREQ guidelines [31], the second through fourth authors conducted the research interviews. The researchers were male and female graduate students with bachelor's degrees. No participants had prior relationships with the researchers, and all were explained the reasons for conducting the research as a part of the IRB-approved informed consent process. The Moravian University Institutional Review Board approved this study and agreed to provide ethical oversight.

2.2. Participants

Participants were a convenience sample. The aim was to recruit between 10 and 20 participants, which is in alignment with sample sizes obtained in previous mixed method immersive IVR studies on initial feasibility and usability [18,32,33]. Inclusion criteria were older adults who 1. were 65 years old or older, 2. were living in the community (i.e., not institutionalized nursing care), and 3. demonstrated intact binocular vision, determined through the task completion of reading the Informed Consent document. The exclusion criteria of this study followed the Meta Quest Pro manual recommendations (https://www.meta.com/quest/safety-center/quest-pro/#manuals accessed on 19 September 2023) along with exclusions due to vestibular complications [26]. The exclusion criteria were as follows: (1) history of vertigo, dizziness, or motion sickness, (2) history of seizures or epilepsy, (3) contagious skin and eye conditions, (4) light sensitivity, (5) use of hearing aids, and (6) pacemakers or defibrillators.

Recruitment occurred through email distributions to community partners. Researchers were initially in contact with 22 individuals who expressed interest in the study. Seven of these individuals did not participate in the study, due to not meeting the inclusion criteria (n = 2), scheduling conflicts (n = 2), undisclosed illness (n = 2), or transportation barriers (n = 1). At the closure of recruitment, fifteen (n = 15) of the total 22 people contacted were enrolled and participated in the study. Data were collected in a private exam room in the Moravian University Rehabilitation Sciences Department with nobody present except the participants and researchers.

2.3. Procedures and Instruments

Participants completed a demographic questionnaire after signing the informed consent. Participants then completed the Quality of Life Scale (QOLS) before the IVR session. For this initial cross-sectional usability study and integrating the focus of older adults' QOL, the QOLS was used to provide an understanding of the sample and test the potential integration of the assessment in preparation for follow-up studies to use the programming protocol. The QOLS is a 16-item questionnaire covering the domains of physical, psychological, social, personal, and independent well-being to measure an individual's perceived QOL and satisfaction [34]. Total scores range from 16 to 112, with scores above 70 indicating a good QOL [34]. The QOLS has high internal consistency, verifying that the questions measure the construct of QOL and has been found to be reliable within primary care settings that included older adults in the validation sample [35,36].

The Canadian Occupational Performance Measure (COPM) was used to inform the selection of the IVR apps used during the session, by first identifying the issues that matter to the individual older adult regarding daily function [37–39]. The COPM is self-reported and reflects the clients' prioritization of five self-identified meaningful daily activity areas, known as occupational problems [40]. The psychometric properties of the COPM when tested with home-dwelling older adults include adequate content validity, construct validity, and feasibility [39]. The COPM has been used previously in IVR studies with older adults [41]. To establish rapport conversationally with patients, the COPM manual does not provide standardized questions for the semi-structured interview [38].

However, to provide a similar app-matching process for all participants, the research team developed a guided script to conversationally ask questions to identify occupational performance problems. The script allowed for a full examination of the three occupational areas of self-care, productivity, and leisure, while guiding the conversation toward areas that were realistic for IVR engagement. For example, within self-care, the guided prompt was to think about personal care, functional mobility, and community management limitations. If a participant responded with "morning self-care routine", the guided prompt then furthered the conversation to, "Some people think of self-care in how one cares for their internal, as well as external, self. This might be through reflections on their routines, for example, in mindfulness practices. Is something like this important to you, but might be difficult for you to accomplish?" All responses were recorded by the researcher but allowed the team to further the interview through all areas of occupations, in depth. Then, the responses were reviewed by the researcher and then ranked by the participant to identify the top five COPM responses. From the list of five occupational problems, the researchers then reviewed the occupational problems with the potential matches of available apps to best align with the occupational interests. For example, if a participant ranked "sail boating" as a top occupational problem, however, boating was not an available app, the researcher asked the participant if the "Fishing" app was a suitable alternative to sail boating.

IVR sessions were in a private exam room with a researcher, with the participant sitting for the entirety of the session (see Figure 1). A cybersickness symptom checklist was established prior to use, with education on potential minor symptoms and 10 min cybersickness safety checks. Each participant was oriented to a 5 min learning session with the Meta Quest Pro (https://www.meta.com accessed on 27 September 2023) using the built-in orientation guide to navigate how to use the two hand controllers and explore the virtual environment, with the headset on.

Figure 1. Private exam room set up of a participant safely seated and interacting with the immersive virtual reality system.

Participants completed one 15–30 min IVR session with pre-downloaded apps on Meta Quest Pro. Apps were aligned with participants' responses based on the COPM top five important occupational problems to address. The research team viewed a live screencast simultaneously to provide support, such as visual and physical prompts when needed, while the participant engaged with the IVR system. Researchers initiated a verbal prompting check every 10 min to ensure that the participant was not experiencing adverse symptoms.

2.3.1. Quantitative Strand: System Usability Scale (SUS) Data

After the IVR session, each participant completed the System Usability Scale (SUS) on the usability of the IVR. The SUS is used for measuring effectiveness, efficiency, and satisfaction with technology [42]. Composed of 10 Likert scale questions ranging from "strongly disagree" to "strongly agree", the SUS is reported as a composite score ranging from 0 to 100 with a higher score indicating greater usability. It has been used with older adults to examine the ease of use when exploring new technology [43]. Generally, scores above 68 indicate good usability for an older adult [43–46]. According to Mol and colleagues [47], the psychometric qualities of the SUS include suitable reliability and adequate convergent validity.

2.3.2. Qualitative Strand: Interviews

The SUS was followed by qualitative open-ended interview questions that explored the user's perceptions of the experience. The interview guide was developed by the research team for this study based on existing published studies and the first author's IVR research expertise, utilizing key content to probe feasibility and usability [9,26] (Appendix A). The interview guide was reviewed by an expert qualitative researcher, not associated with the study, for clarity and the identification of leading or biased questions. The guide was revised accordingly. The research interviewers practiced conducting the interviews with the first author for approximately two weeks until standardization aims were met. Interviews were conducted face-to-face immediately after the IVR experience and recorded using Zoom cloud (https://zoom.us accessed on 14 November 2023). The questions were presented in a conversational manner to the participant. Researchers maintained a journal of their experiences during data collection for reflexivity, known as the critical self-reflection of the relationship to the participant as the moderator for the participant to engage with the IVR system, and how this may have affected the participant's answers during the interview [48]. The journaling also included persistent observations of how participants interacted with the system, including initial reactions, adjustments, and specific challenges or benefits they encountered, to ensure credibility [48].

2.4. Data Analysis

Demographic data were analyzed in Excel to summarize and to describe the sample. The COPM responses of preferred engagement in occupational activities were examined descriptively through frequency counts, as well as reports of simulator sickness to further inform feasibility.

2.4.1. Quantitative Strand: System Usability Scale (SUS) Data

The quantitative strand of the SUS scores were descriptively analyzed by calculating the mean as the measure of central tendency and the standard deviation to account for variability, to interpret usability scores reported. Then, the participant's SUS scores were ranked based on usability scores to systematically analyze transcripts. The transcripts of the three lowest, the two middle, and the three highest SUS scores were analyzed for coding.

2.4.2. Qualitative Strand: Interviews

For the qualitative strand, the interview was audio-recorded and was automatically transcribed through the Zoom cloud recording and then downloaded to a standard VTT file. Transcripts were then cleaned by the researcher who conducted the interview. A directed approach to content analysis was followed by utilizing predefined categories based on prior research in the field of technology feasibility, of the categories of acceptability (including learning), practicality, and implementation, while remaining flexible in the application [49].

The first author read through all VTT file transcripts and ensured that the categories of feasibility and follow-up probes had emerged through the interview. To complete the systematic coding of the textual data [49] to further investigate the aim of feasibility, the SUS-ranked transcripts provided rich detailed data during the interview. The range of usability reports and perspectives of the varied participants' responses addressed the potential themes and potentially allowed for the identification of new categories that emerged during the analysis process [49]. Manual coding of the VTT file transcripts was independently completed by two researchers. Then, during in-person meetings, the agreement of codes was identified, quantified, and organized into the predefined theme categories of feasibility, any disagreements were discussed, the journaling of the sessions was reviewed, and agreement was settled by the first author. Researchers interpreted the contextual interpretation findings within predefined categories and discussed any new emergent that was not anticipated initially and to understand the quantitative results of usability [49]. The researchers remained flexible in this approach to make meaning of the unanticipated data and reached agreement within the predefined categories and achieved saturation among the transcripts analyzed.

2.4.3. Trustworthiness of Data

For trustworthiness, the team used the triangulation of data to enhance credibility and the depth of findings. Triangulation was achieved by integrating journaling data with System Usability Scale (SUS) scores and interview transcripts. During the 15–30 min IVR protocol, each researcher journaled experiences that occurred during the session. Content analysis revealed that while interview transcripts provided comprehensive narratives, journaling added layers of personal reflection and emotional context, enriching our understanding of the participants' experiences. This integration underscored the importance of multi-source data in capturing the complexity of user experiences in qualitative research. By cross-referencing these journal entry accounts of each participants' session with the COPM-identified preferred occupational engagement activities and SUS scores, we could contextualize participants' usability ratings, offering deeper insights into their interactions with the IVR system.

2.4.4. Reflexivity

For group reflexivity, the Principal Investigator's previous research experiences with VR were utilized which included her reflection on the positive and negative reports of technology from the perspectives of older adults. This eliminated prior personal experiences, assumptions, and beliefs from the 15–30 min IVR intervention, which was not carried out by the Principal Investigator. In alignment with the directed approach to content analysis, the predefined categories for coding were determined through a group consensus of feasibility, including learning, practicality, and overall impressions of implementation of the system.

3. Results

3.1. Sample Characteristics and Preferred Occupational Engagement

The demographics of 15 older adult participants included the following: an average age of 76 years old (SD = 6.2) and similarly sized groups of males (n = 7) and females (n = 8) (see Table 1). Nine of the participants were post-bachelor's degree educated, three had a bachelor's degree, two had a background of a technical degree or some training, and one had some college completed. Racially, all the participants (n = 15) were white. At baseline, the QOLS average was 96.27 (SD = 10.88), with a range of 72–109, which indicated a "good" perception of quality of life among the 15 participants. A QOLS score of 70 or higher is considered "good", and typically, individuals who report a good QOL are also considered to be healthy [35]. Additionally, nine individuals disclosed a report of a health condition, the majority reported arthritis (n = 7), as well as hypertension (n = 2), a medically managed blood clotting disorder (n = 1), and prostate cancer (n = 1).

Table 1. Baseline characteristics (n = 15).

Demographics	N (%) or M (SD)
Age (in years)	76.53 (6.2)
QOLS	96.27 (10.7)
Gender	Male = 7 (46.7%) Female = 8 (53.3%)
Education	Postgraduate = 9 (60%) Bachelor's = 3 (20%) Technical/Training = 2 (13.3%) Some College = 1 (6.6%)
Race	White = 15 (100%)

Note: QOLS = Quality of Life Scale.

Through the COPM, participants self-reported the importance of preferred activities on a scale of 1 to 10 of 1 = not important at all to 10 = extremely important in the COPM areas of self-care, productivity, and leisure; then, they were matched with apps relating to the participants' preferences. Some apps applied to multiple areas of occupation; for example, the occupation of walking may have been the COPM sub-area of functional mobility, while it could be considered by others as a COPM sub-area of active recreation. Participants were offered more than one matched application to satisfy their areas of importance and 18 app trials with 15 participants resulted. Based on the distribution of areas of importance and the number of participants (n = 15), seven of the apps were in the domain of self-care, two were productivity, and six were leisure. Eleven participants engaged with an activity that matched their top-ranked occupation of importance (Table 2).

Table 2. List of apps and the occupational area addressed, and the number of uses with participants.

IVR Applications	COPM Areas	COPM Sub-Area	# of Uses (18)
Fishing	Leisure	Active Recreation	1
Gravity Sketch	Leisure	Quiet Recreation	1
Hoame	Leisure	Quiet Recreation	1
National Geographic	Leisure Productivity Self-Care	Active Recreation School and Play Personal Care (1)/Functional Mobility (4)	2 1 5
Nature Trek	Leisure Productivity Self-Care	Active Recreation School and Play Personal Care	1 1 1
Tripp	Self-Care	Personal Care	1
YouTube VR (Driving and Nature Trails)	Self-Care	Functional Mobility	3

Note: COPM = Canadian Occupational Performance Measure.

Regarding the reports of simulator sickness, two out of 15 participants reported symptoms, which were minor neck pain and dizziness exacerbated by YouTube VR (Driving) and National Geographic. Both reports of simulator sickness were resolved after a 5 min rest break, and IVR was then continued with a different app.

3.2. *Quantitative Strand: System Usability Scale (SUS) Data*

Usability, as measured by the SUS, was an average of 55 (SD = 23.95), indicating a wide dispersion of responses. Of the 15 SUS responses and considering the cut-off minimum of 68 to determine a system to be usable, only five participants reported usability over 68, warranting further investigation.

3.3. Qualitative Strand: Content Analysis of Interviews

The following main themes related to feasibility emerged: (1) participants required various levels of initial learning support, and their learning experiences were related to user confidence; (2) the practicality of the matched IVR apps for that individual's engagement-related to perceptions of positivity; (3) the overall feasibility and impressions of the given IVR protocol varied among participants, based on a combination of the apps used and their learning experiences. No themes emerged from top-importance application matches finding IVR to be usable, as participants who engaged with an activity of lower importance still found IVR to be personalized for them. The content analysis table is summarized in Table 3, with further quotes elucidating deeper insights discussed in the next section (please see Section 4).

Table 3. Content analysis with the System Usability Scale (SUS) ranking and connections.

Predefined Category	Theme	SUS Rank Connection	Subthemes	Example Quotes
Acceptability	Usable when intuitive and with training	Low	Difficult Not intuitive	"You need a lot more training for a first-time user. It's not intuitively obvious what you have to do to make it work, even though it's quite simple, once you know it. It's not intuitive." (Participant 06, SUS = 35) "You know it was awkward with the buttons and the controllers, I didn't know what they did." (Participant 07, SUS = 22.5)
		Middle	Needing assistance	"I couldn't see where my fingers were supposed to go. . .I didn't know which thing to press (Participant 15, SUS = 70)
		High	Easy	"I think it's something that especially older people could use" (Participant 12, SUS = 75)
Practicality	Balance the app choices for success	Low	Negative Impractical Limitations Not engaging	"I didn't really learn too much." (Participant 04, SUS = 17.5) ". . .no favorites." (Participant 06, SUS = 35)
		Middle	Positive Practical Realistic	"By all means, as I'm saying, it gives me an opportunity to do something which I may not be able to do nowadays, because of both mine and my wife's age and my wife's health conditions." (Participant 09, SUS = 62.5)
		High	Engaging Opening opportunities	"I love the virtual environment I just engaged in. . . it made a really vivid impact on my psyche." (Participant 05, SUS = 95)
Implementation	Lasting impressions were related to the perceived implementation	Low	Disappointed Complicated	"I'm disappointed. it didn't work. I wanted to have some fun."(Participant 04, SUS = 17.5)
		Middle	Clever Good Creative	"It was very clever, creative, and it gave me a chance to do something I hadn't done before." (Participant 01, SUS = 65)
		High	Fascinating Surprising Interesting	"It exceeded my expectations definitely, because it had a chain reaction to my sense of well-being when I came out of it, left me in a state of extremely relaxed absence of hunger; and really desire to experience more." (Participant 05, SUS = 95)

4. Discussion

This study aimed to explore the feasibility, including the learning experiences and usability of a defined protocol for matching immersive virtual reality (IVR) to meaningful occupations for community-dwelling older adults. The study utilized a newer IVR device (e.g., the Meta Quest Pro), screencast connection, and trialing the feasibility of matching apps to meaningful IVR engagement for up to 30 min. The results suggest that participants' experiences varied widely in relation to the reported data. Wide variations are also seen in systematic reviews of the usability issues of virtual reality [18], and as IVR operating systems are constantly updating and hardware is upgrading, the mixed methodology is helpful in understanding the bigger picture of the varied range of the SUS responses.

The examination of feasibility is most related to usability, which was measured with the SUS reports. SUS post-IVR reports ranged from 17.5 to 95, and five of the 15 participants reported the recommended cut-off of usability (SUS score > 68) for the IVR system. This prompted an examination of the most varied quantitative SUS scorings of usability to provide deeper insights into the connection to usability perceptions, with SUS score connections reported in Table 3, and emerged as the theme that the system is "Usable when intuitive and with training". Transcripts reviewed suggest that the organization and numerous buttons on the control interface could be a factor impacting usability. One participant, who reported being left-handed in their interview, mentioned how she was dissatisfied with "having to switch left hand to right hand" and stated it is a "right-handed world" (Code 03). In this specific case, this user's experience suggests that the IVR device was not universally designed for all participants, regardless of varying factors, such as hand dominance. These discrepancies in design might have contributed to errors or difficulties that older adults experienced during the IVR sessions. Another participant, who otherwise reported a suitable usability score of 70, reported "It was just my hands. I couldn't see where my fingers were supposed to go. . .I didn't know which thing to press" (Participant 15). When asked what aspect they were dissatisfied with, another participant with a SUS score of 50 reported "my inability to use the right buttons" (Participant 14). To enhance usability among older adults, it is recommended that future studies consider apps that do not require control interface button triggering and rely only on hand tracking, as well as extending examinations of usability over multiple sessions for learning.

Other factors of technology difficulties or technology-positive perceptions may have contributed to the usability reports among participants. Apps, such as National Geographic exhibited performance disruptions and user inconsistencies. For example, one participant who reported a SUS score below the 68-usability cut-off, still reported a positive IVR experience, with ". . . like I said the interface being locked onto that one task made it very difficult" (Participant 07). Researchers faced technical difficulties when utilizing the screencast from IVR to a tablet, which may have contributed to technology insecurities and low usability scores among participants. It is important to note that while older adult experiences with IVR were both positive and negative, those who reported low usability did not necessarily report negative experiences in the qualitative interview. For example, Participant 07 reported a SUS score of 22.5, but when asked if the session was like they expected, they reported "No, it was actually better" and that it was "a lot of fun". Similarly, regarding satisfaction, Participant 05 reported, "I love the quality of the narrative. The narrator's voice, the well-thought-out guidance, and the actual movement dynamics that were going on in the visuals that I was watching. . . appealed to my area of interest and it did so with an excellent voice quality, fascinating, engaging, visual and meditation guidance that made sense to me. And instructional guidance that I could follow easily". This quote was in response to the meditation app Tripp, which provides meditation with digitally pre-recorded voice guidance. Participant 05 reported a SUS score of 95, which may have been related to both his meaningful area of interest paired with the in-app learning support. Although for this study, cognitive status was unknown for these community-dwellers living independently, the ease of interaction should be considered across the cognitive functioning continuum. IVR is feasible for older adults with cognitive impairments and dementia when the operations are more passive and do not require motor control synchronization for interactions, such as displaying scenery imagery [22,28]. Future studies may find that apps designed for ease of use, with minimal controller interface input required and with built-in guidance may enhance usability perceptions.

As for the apps included within our study available for participant interaction and directly related to the research question, content analysis revealed that study participants required various levels of initial learning support, and their experiences depended on their confidence to use the IVR. Key descriptions of the learning experience ranged among difficult, needing assistance, easy, and not intuitive. Specifically, when asked about learning IVR and how to provide support, one participant explained "I think there needs to be someone who would walk them through that. Probably have a little videotape going and then showing someone learning how to use it, and some of the issues that they've confronted, but how they solved them, and then go on to have people use it. Possibly even as a class" (Participant 01). This participant also reported that they "feel very confident" when asked about confidence in IVR abilities following the session. These suggestions are in alignment with recommendations that teaching techniques are more consistent when given repeatedly [50]. Participant 06, who had an overall negative experience and a low SUS score of 35, reported "the learning" to be his least favorite part of the experience, stating that "you need a better learning experience". This participant also stated that they would not use IVR on their own. For future planning and based on the qualitative findings, providing initial assistance and support when using IVR, such as a more detailed and tailored orientation course, may help to improve user competence and improve the learning experiences for older adults using IVR.

Based on the qualitative analysis, learning experience reports did not necessarily align with practicality perceptions, resulting in the theme of "Balance the app choices for success". For example, although some participants reported that they needed assistance (Participant 09) while learning and that it was not intuitive (Participant 07), these same participants reported that IVR was practical for them. In other cases, some participants found that learning to use IVR was difficult (Participant 01), or they needed assistance and that IVR was overall impractical for them. Others reported that learning was easy and IVR was practical for them. Regarding this concept of practicality and the theme that participants' practicality perceptions related to their overall positive and negative experiences, responses ranged from practical to realistic to impractical. Activity engagement or participation within the IVR application can be summarized as engaging, realistic, opening opportunities, limitations, and not engaging. Participant responses to the theme of practicality provided the researchers with an understanding of the real-life application of IVR among older adults and that the choice of an app being easy to use should be weighed with how engaging and realistic the app may be, as a balance for each individual person. Participant 12 reported, "it gave me a chance to see some things that I would not normally see", who also reported a SUS score of 75 for IVR.

Within this notion of balance, previous literature suggests that older adults' positive perceptions of the relevance of new technology will improve the learning and engagement experience [16,50]. Utilizing occupation-based apps on IVR kept various participants engaged and defined a purposeful use in their everyday life, as Participant 05 reported ". . . and if I had the VR, I would do my private meditation with it on. Actually, I would use it for a timeout device to refocus and recenter myself throughout the day". Contradicting this, Participant 01 reported "You know, if I saw the benefit of it, that'd be no problem". The difference in responses could be due to the various apps in which the participants engaged, as everyone was matched with their own interests. Establishing the interests of older adults is key to occupational therapy practice, as it is a profession prioritizing client-centered care. Previous literature supports that positive aging outcomes are linked to meaningful engagement opportunities [33]. The findings of this study and app matching engagement may be implemented by occupational therapy practitioners to provide a variety of healthy aging-in-place interventions with the emerging technology for older adults.

When examining overall implementation, the theme of "Lasting impressions were related to the perceived implementation", was based on a combination of the apps used and their learning experiences. Thus, Figure 2 visually represents the prior two themes of decision-making for usability, training, and the consideration of the balance with engagement for a successful session, which may impact the overall impressions. Qualitative results included a mix of negative and positive perceptions, ranging from reports of overly complicated apps to reports of the apps being clever, fascinating, interesting, and fun. Participants who reported positive experiences also found IVR to be engaging and practical. Participants who reported an overall negative experience found IVR to be impractical and limited. Despite participants recognizing that there are limitations to IVR, there were positive responses. These responses reflected only one session of IVR training, which may not have been sufficient time to ensure usability among older adults. As previous literature suggests, learning new tasks of engagement is beneficial for productive aging but must be incorporated into everyday routines [5].

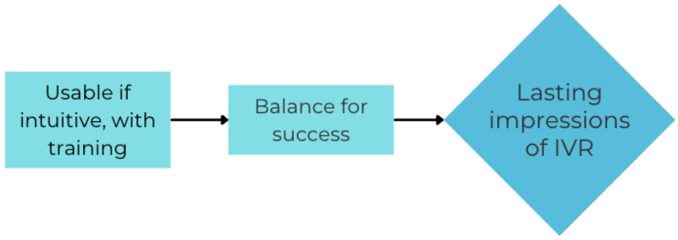

Figure 2. Visual representation of themes of occupation-based IVR.

Based on the apps utilized, the most engaged in COPM domain was self-care, which is aimed at occupations that get the individual ready for the day and how they move around. Within self-care, there are subcategories of personal care, functional mobility, and community management. Personal care occupations include basic living activities, such as dressing, bathing, feeding, and hygiene [38]. More specifically, the self-care sub-areas of personal care and functional mobility were addressed the most in the participants' experiences. The apps that were associated with these sub-areas were related to meditation, walking, traveling, and driving. This aligns with previous literature of situational familiarity of the scenes [23]. In the domain of self-care, walking was an occupation that four participants reported as their top importance. It is important to note, however, that the apps in the self-care domain did not address the entire spectrum of occupations that participants expressed interest in. For example, some participants expressed activities, such as reading and going to church, as preferred self-care activities, in which our app library was not able to match.

The second highest engagement in the COPM domain was leisure, more specifically active and quiet recreation. Previous literature has shown that older adults prefer leisure-related activities regarding IVR [51,52], as tasks may provide a sense of realization and belonging [52]. The occupations of interest associated with these sub-areas were meditation, painting, travel, fishing, and walking. Nature walks and painting with IVR were not able to be accommodated. In the COPM domain of leisure, travel was an important occupation that two participants addressed during their IVR session. When asked about interest in using the IVR apps to do other activities of interest, one participant explained "Having literally traveled all over the world. It's not part of my present time reality, but I would love to experience travel through this kind of device" (Participant 05). Another participant described how IVR would be beneficial for his wife and him to use for travel experiences: "I think it's something that especially older people could use. Like I explained to you before, we travel a lot extensively around the world. But there's still a lot of spots we haven't seen, and I would dearly love to have that available on VR, so that I could, I could see the virtual reality" (Participant 12). Overall, based on the participants' chosen areas of interest, the occupations with the highest engagement include walking (n = 6) and travel (n = 5). These reports are similar to previous feasibility participant requests for more engagement in city life and mountain adventures in nature [22].

Limitations

The findings of this study cannot be generalized to how the population might perceive IVR, due to various demographic factors, the limited comprehensive pre-session intake questionnaire and physical examination, and limited sampling. The study's participant pool lacked diversity as all participants pursued some form of higher education, were white, and presumably encountered normal aging conditions. Cognitive status is unknown for the participants, as well as their previous exposure to IVR and the native language of the participants; however, all were able to read English through the Informed Consent. Some participants (n = 7, 46.7%) reported the condition of arthritis, which is a similar distribution to CDC reports of 47.3% of adults aged 65 and older being diagnosed with arthritis [53]. To enhance the understanding and generalizability of older adults' experiences with IVR, future research should strive to include participants from a broader range of demographic backgrounds, such as varied ethnicities, education levels, and the intake of cognitive status, as well as previous experiences with IVR.

A further limitation of this study is the selection of apps that were offered to participants. Our participant pool lacked diversity, and along with the limited variety of available IVR apps not fully representing the diverse occupational interests of older adults, this affects the study's relevance to a broader older adult applicability and engagement. While the downloaded app library was sufficient to match with at least one of every participant's COPM occupations of importance, some apps overlapped and there was only one app choice for some COPM sections. For this reason, some participants did not feel like there was an appropriate application for their interests and their COPM responses. In the future, providing a larger selection of apps may allow participants to be better matched with an application of their interests. For example, previous studies have referenced utilizing leisure-based apps with multi-sensory and physical experiences, such as gardening and traveling without risks, such as in ocean and mountain environments [19,45]. Another study referenced utilizing a simulated kitchen environment application [46]. According to this research study, older adults are ranking their topmost important occupations as nature walks, driving, meditation, cooking, traveling, prayer, and card games. As mentioned, not all preferred occupations were available as apps, which included not finding matches for cooking, nature walks, prayer, and card games, and future IVR studies should include important occupations in app libraries as important occupations for older adults. Based on the literature, leisure is an area of interest for the older adult population [51,52], and future studies should expand the leisure library of apps for older adults. Current IVR research examines apps that cover health outcome areas of overall QOL, such as physical, social, psychological, and cognitive well-being without specific apps being discussed [15]. It should also be noted that a single IVR session likely did not capture the long-term usability of the IVR system and of the matched apps for older adults and that the app duration was not recorded. Multiple-session usability and the duration of apps should be further examined prior to trialing the effectiveness of the protocol for QOL outcomes and consider that IVR procedures carry out eight to nine sessions in previous studies [28,51]. In addition, a clearer picture of the significance of the type of occupational engagement of the app and the potential influence on usability is warranted through a controlled study comparing apps of occupational preference for older adults.

Another limitation would be considering if the COPM was an appropriate assessment for the participants to report their meaningful occupations. Since the COPM probes the categories of interest of self-care, leisure, and productivity, this does not leave room for the self-guided exploration of ideas and interests. A previous study utilized multiple sources of information, such as patient, staff, and family, and geolocational-related information to personalize their IVR session with older adults [30]. Other assessment considerations that may apply to open conversations of activity interests include the Activity Card Sort [54], which allows for the ranking of activities based on potential leisure exploration. Regardless of the assessment method, a comprehensive client-centered approach should be implemented to provide researchers with in-depth information to better tailor IVR apps to personal interests, perhaps utilizing semi-structured interview methods to personalize the IVR apps.

5. Conclusions

Overall, the research team was able to determine that IVR and the integration of meaningful engagement within relevant apps is feasible. These findings were based on one 15–30 min session of IVR engagement matched to their important occupations, with considerable variability in participant responses based on learning, practicality, and usability. However, with the supportive structuring of learning and matching of the apps and expanding the apps to more offerings related to older adults' interests and spanning multiple areas of occupational importance with an emphasis on leisure, older adults who are open to novel technology in their lives may find IVR to be beneficial in enabling them to participate in preferred and relevant occupations as they age. As previous literature states, incorporating functional tasks in a simulated environment using IVR has been found to aid in managing mental health-related and physical aging declines [55,56], with positive experiences when presented with personalized and exciting IVR apps [32]. This study built upon this existing research by trialing a defined protocol utilizing the COPM, to match participants with relevant apps. Expanding on the number of apps available with supportive learning may make the app-matching more feasible for a wider variety of older adults to reap positive potential outcomes.

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Appendix A

Interview Questions

What were your initial impressions about VR?
  Probe: Where have you seen VR before?
  Probe: Was this VR session like you expected?
To what extent were you satisfied with the VR program?
  Probe: What about your application did you like?
  Probe: What parts would you say were your favorite?
To what extent were you dissatisfied with VR?
  Probe: What about your application didn't you like?
  Probe: If anything, what about it would you like to have changed?
How would you describe your experiences with learning to use VR during the session?
  Probe: What parts did you find easy?
  Probe: What parts did you find hard?
How should support or assistance be provided for VR?
  Probe: How did you feel about having someone with you to help you along by seeing what you see on the screencast?

Probe: Do you think having someone with you during the use of VR with the screencast is necessary?

How would you feel about using VR on your own?

Probe: How confident would you say you feel in your own abilities after this session?

Probe: Do you think this session prepared you well if you were to use VR in a different setting?

Did you find the VR program to be practical for you?

Probe: Did you think VR allowed you to participate in an activity of interest?

Probe: How interested are you in continuing to use VR to do other activities of interest in the future?

Probe: Did the VR applications fit with your abilities to participate?

Overall, does the VR session contribute to your ability to engage in an activity?

Probe: How so?

Probe: What are your thoughts on the virtual environments in which you engaged?

Probe: Do you think the pre-interview questions in the beginning helped us to match you with a VR app that you were interested in? Were there limitations?

Probe: How interested would you be in using other VR applications to do your other activities of interest?

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