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# Comparison of informational and experiential interventions for VR acceptance in rural older adults: a feasibility study

*Summer Abigail Fox MSc[a], Aidan Stewart Fisk BSc[a,b], Daniel Herman Blustein PhD[a,b]*
*[a]Department of Psychology, Acadia University, Wolfville, NS, Canada; [b]Valley Regional Hospital, Nova Scotia Health Authority, Kentville, NS, Canada*

*Corresponding author: blustein.neuro@gmail.com*

**Abstract**
**Background:** Virtual reality (VR) offers a promising solution to deliver portable, engaging rehabilitation services, particularly for rural populations with limited access to care. However, its adoption among older adults may be hindered by key barriers, including technological unfamiliarity or concerns about visually induced motion sickness (VIMS). Overcoming these initial acceptance barriers is a critical step for implementing this gerontechnology, which could deliver physical and mental health support directly to the homes of older adults.
**Research aim:** We aimed to determine the feasibility of using brief, low-resource interventions, either an informational handout or a short immersive VR experience, to improve attitudes toward VR in rural older adults.
**Methods:** In this comparative feasibility study, sixty-four rural adults aged 60 and older received either an informational handout describing VR or completed four immersive VR activities using hand tracking on a consumer headset. Attitudes toward VR and VIMS symptoms were assessed using pre-post intervention surveys.
**Results:** The immersive VR experience did not result in a significant increase in VIMS symptoms, demonstrating high tolerability. Both the informational handout group and the VR experience group showed significant positive improvements in attitudes toward VR.
**Conclusions:** Brief, low-resource interventions can increase technology acceptance for VR among rural older adults. The finding that a simple informational handout can be as effective as a hands-on immersive experience has significant, practical implications for the scalable and cost-effective deployment of VR-based technologies in clinical and home-based gerontological settings.

Keywords: virtual reality, technology acceptance, older adults; rural health, gerontechnology

## Introduction

Older adults in rural settings often face barriers to maintaining social connection (Walsh et al., 2020), engaging in physical activity (Wilcox et al., 2000), and accessing medical care (Shanmugasegaram et al., 2013). Healthcare access disparities are particularly critical in specialized, time sensitive domains like rehabilitation following surgery, stroke, or other emergent health conditions. Virtual reality (VR) has shown the potential to deliver health services directly to older adults, subsequently improving quality of life (Aldardour & Alnammaneh, 2025; Lal et al., 2023). VR-enabled benefits for older adults have been shown to span cognition (Tortora et al., 2024), balance (Lee et al., 2024), motor function (Kashif et al., 2022), and physical activity (Jaunbuccus & Elaheebocus, 2024). Yet in many real world contexts, adoption, and not efficacy, remains the limiting step, particularly for first time older adult users in rural communities (Hepburn et al., 2025).

Rural older adults face distinct barriers to specialized medical care, including geographic isolation, transportation costs, and limited local access to specialists (Shanmugasegaram et al., 2013). These disparities are apparent in time-sensitive rehabilitation for stroke (Hammond et al., 2020), orthopedic surgery (Long et al., 2023), and cardiac care (Shanmugasegaram et al., 2013), where rural patients often experience fewer specialized interventions and higher post-operative complication rates. While portable virtual reality (VR) offers a promising telerehabilitation solution to bridge these gaps (Faria et al., 2016; Ögün et al., 2019), rurality also brings significant structural obstacles. Lower broadband penetration and limited opportunities for technical support in remote areas create high "entry costs" for technology adoption (OATS, 2025). When combined with lower digital literacy, rural seniors face intersectionally compounding barriers that can stall the adoption of even efficacious interventions (Roberts & Mehrotra, 2020).

Although the COVID-19 pandemic accelerated a shift towards in-home telemedicine, rural disparities persist. Despite rising technology use and internet connectivity among older adults (Kakulla, 2025; Lee et al., 2023; OATS (AARP), 2025), rural patients use video visits (Ferrara et al., 2025) and patient portals (Bhavsar et al., 2022) at significantly lower rates than their urban peers. This persistent digital divide underscores the need for accessible, low-friction engagement onboarding strategies (e.g., brief, plain language materials). Addressing psychological barriers to adoption, including technological anxiety and perceived safety, is a prerequisite for equitable health technology deployment in resource-constrained rural settings. Technology acceptance models (e.g., TAM/UTAUT) suggest that perceived usefulness, ease of use, and social endorsement are central to eliciting intention among older adults to try a new health technology (Hosseini et al., 2024; Roberts et al., 2019; Yang et al., 2025). Preconceived notions and attitudes toward VR could deter rural older adults from trying VR health technologies in the first place. Attitude has been observed as a strong predictor of intention to use telehealth (Tan et al., 2025), while technological anxiety has a negative effect (He et al., 2025). A prior study assessing willingness to use technology for rehabilitation services found that 100% of younger stroke survivors and only 63.6% of older stroke survivors would be interested in using technology for rehabilitation services (Ortiz-Fernandez et al., 2021). This disparity in interest between age cohorts suggests that it could be more challenging to convince older adults to engage with technology based rehabilitation such as VR.

Although prior work suggests many older adults find VR pleasant and useful once they try it (Appel et al., 2019; Arlati et al., 2021), catalyzing initial exposure and, ultimately, adoption remains an important goal. While immersive exposure is known to improve attitudes (Huygelier et al., 2019), it remains a resource-intensive intervention. It is currently unknown whether a scalable, low-cost informational alternative can achieve comparable shifts in acceptance within a population facing barriers to access digital health technologies. Determining this is essential for equitable technology deployment in resource-constrained rural settings.

In rural clinics and community programs, a brief, plain-language informational handout may efficiently address concerns (e.g., purpose, safety, value) and increase perceived usefulness, important factors boosting intention to use health technology identified through technology acceptance models (Hosseini et al., 2024; Roberts et al., 2019; Yang et al., 2025). A short, supervised immersive exposure would likely have a similar effect, with the trade-off of additional implementation resources including equipment, space, staff time, and stable internet connectivity. Here, we seek to determine whether an informational handout can approximate the acceptance gains of a hands-on demonstration, which will directly inform scalability and equitable access related to VR health technologies.

Because perceived safety and comfort can dampen willingness to try VR, we also address visually induced motion sickness (VIMS) as a tolerability outcome. Some users experience nausea, oculomotor issues, and disorientation arising from visual–vestibular conflict in VR, though susceptibility varies across individuals and stimuli (Kim et al., 2018). Notably, recent research indicates that older adults demonstrate higher tolerance to VR and report weaker VIMS symptoms than younger users during task-based interactions (Jochmann et al., 2025). By using short, goal-oriented, seated VR sessions with hand tracking, we expect high tolerability among older adults, which we assessed by measuring VIMS before and after VR exposure.

In this study, we seek to determine whether two brief, low-resource interventions, (1) an informational handout and (2) a short, supervised immersive experience, can shift attitudes toward VR among rural older adults, and whether immersive exposure is well tolerated. We also examine whether individual differences, including gender and prior technology experience, serve as moderators of attitude change. While comfort with technology strongly predicts adoption intention in older adults (Mao et al., 2026), gender's role is inconclusive. A recent meta-analysis found no consistent moderating effect of gender in older adult health technology acceptance (Yang et al., 2025), but since women face poorer overall health outcomes (Heart & Stroke, 2018) and are underrepresented in clinical research (Daitch et al., 2022), the inclusion of gender as an exploratory demographic factor is important. In rural settings specifically, gender disparities in technology access (Kim et al., 2017) could lead to different degrees of digital readiness to try health technology, ultimately exacerbating health inequities (Tung et al., 2024). By comparing a minimal-resource handout to a hands-on demonstration, and exploring moderating effects, we aim to inform scalable, equitable access pathways for VR telerehabilitation in rural older adult populations.

**Hypotheses**

Given previous findings (Dockx et al., 2017; Huygelier et al., 2019; Syed-Abdul et al., 2019)

and the limited understanding regarding acceptance of task-based hand-tracked VR technology and VIMS in rural older adults, the hypotheses for our research are as follows:

*Hypothesis 1 (Tolerability):* Participants will not experience significantly greater symptoms of VIMS during the VR experience when compared to their baseline symptoms (predicted due to recent improvements in VR capabilities and embodiment).

*Hypothesis 2 (Acceptability):* Exposure to an informational sheet and to a brief, immersive VR experience will both positively influence rural older adults' attitudes towards VR.

*Secondary Hypothesis 1:* Actively engaging with the VR system will be more effective for positively changing attitudes than reading an informational handout about VR.

*Secondary Hypothesis 2:* Being inexperienced with technology prior to the VR exposure will predict a greater attitude change in a positive direction when compared to being experienced with technology prior to the VR exposure.

## Methods

### Transparency and openness

We report the sample size power analysis, random assignment procedures, and recruitment methods (*Supplemental Note 1*). Data and code are available on the Open Science Framework (https://osf.io/zk769/). Analyses were conducted using the R programming language (version 4.3.2). Our study and data analysis plan were not pre-registered.

### Safety and ethics

Ethics approval was obtained from the Acadia University Research Ethics Board (REB File # 23-08). VR participants remained seated while wearing the headset to reduce the risk of falls. They were informed that some individuals experience motion sickness when using VR, and they were instructed to tell the experimenter if they began to feel unwell. All participant testing took place at Acadia University between June 2023 and October 2023.

### Participants

Participants were adults over the age of 60 from the Annapolis Valley, Nova Scotia, Canada. Two were excluded due to incomplete data. See *Supplemental Note 1* for complete eligibility criteria and detailed recruitment procedures. Participants received a $10 gift card for their involvement.

### Design and procedure

We used a between-subjects design with participants randomly assigned to a first-person VR condition or an informational handout condition (n = 32 each, *Supplemental Figure 1*). Randomization was performed using block stratification following a pilot study (n = 13) that was used to validate system functionality and refine the VR instructions (*Supplemental Note 1*).

Participants first completed a pre-intervention survey collecting demographic information and self-reported prior VR experience, comfort with technology, and attitudes toward VR (*Supplemental Table 1*). Following the assigned intervention, participants re-rated the VR attitude statements, and the mean attitude change score was calculated for each participant.

In the VR condition, participants completed four custom VR experiences coded in the Unity game engine (Fisk et al., 2025) and running on the Meta Quest 2, a consumer-level head-mounted display (HMD) VR system (see Figure 1). The 15-minute VR experience was designed to be an engaging, user-friendly introduction to the technology using a virtual coach who responded to voice commands. Additionally, the use of hand tracking meant that participants did not hold game controllers or learn interaction button configurations, allowing for more intuitive interactions in the virtual environment. The tasks were designed to capture different critical motor skills that are often targeted through rehabilitation interventions, including gross reaching, reach and grasp, and wrist rotation. VIMS was assessed before and after the VR experience using the 9-item Virtual Reality Sickness Questionnaire (VRSQ) (Kim et al., 2018) (*Supplemental Note 2*).

In the information condition, participants read a VR informational handout and answered five related trivia questions (*Supplemental Appendix A*). The study concluded following the completion of the post-intervention survey.

### Analytic strategy

Descriptive statistics were used to explore participant characteristics. Changes in attitudes toward VR were assessed using a chi-squared goodness-of-fit test. A multiple regression with 10,000 bootstrapped samples was used to determine whether participants' study condition or their prior experience with technology predicted their attitude change. Cook's distance values were used to identify outliers in our data. Equivalence testing was used to compare attitude change between VR experience and information handout conditions, and to compare VIMS scores before and after the VR experience. We conducted

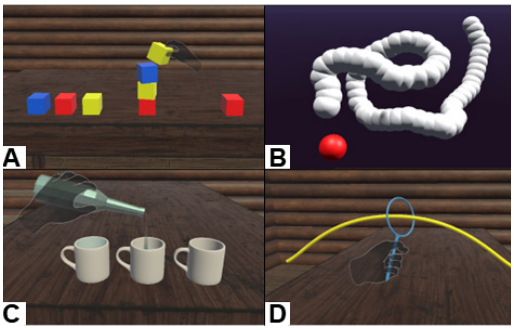



*Figure 1. Activities in the first-person virtual reality condition. The images demonstrate the following virtual reality activities: stacking blocks (A), guiding a caterpillar through a three-dimensional space (B), pouring water from a bottle (C), and guiding a hoop along a wire (D).*

exploratory analyses by comparing effect sizes of attitude change between women and men across conditions. We also used a linear regression to explore the relationship between motion sickness and attitude change. See *Supplemental Note 3* for more details on these methods.

## Results

### Demographics

All 64 participants (M age = 71.3 years; range: 60 – 89; 36 women) completed the study session. Data from two participants were excluded (see *Supplemental Note 4*), leaving 62 for analysis. Of these, 58.1% identified as women (36/62), and 83.9% had no prior VR experience (52/62) (*Supplemental Table 2*). Despite block randomization, more men were assigned to the information condition (17/31), and more women were assigned to the first-person VR condition (22/31). No significant adverse effects were reported or observed.

### Descriptive statistics

*Immersive VR tolerability in rural older adults.* Participants in the first-person VR condition had, on average, a near negligible change in average points per VRSQ statement (M = <0.001 increase, SD = 0.18) (*Figure 2*). The first-person VR experience had a negligible effect on change in motion sickness (d = 0.00, 95% CI [-0.51, 0.51]).

*Immersive VR acceptability in rural older adults.* Across the two study conditions, participants had an average, positive attitude change of 0.98 points per statement (M = 0.98, SD = 0.90), representing a large effect size (d = 1.02, 95% CI [0.64, 1.40]) (*Figure 3*). Only seven out of 62 participants had a slightly negative attitude shift toward VR after participating in the study (*Figure 4*).

Participants in the information condition had a mean positive attitude change of 0.76 points per statement (M = 0.76, SD = 0.87), a medium effect size (d = 0.73, 95% CI [0.21, 1.26]). Most participants had a positive attitude change, with only four of 31 participants showing a negative change (*Figure 4A*). Participants in the first-person VR condition had a mean positive attitude change of 1.19 points per statement (M = 1.19, SD = 0.89), a large effect size (d = 1.37, 95% CI [0.81, 1.94]). Most VR participants had a positive attitude change towards VR, with the exception of three participants (*Figure 4B*).

### Hypothesis testing

We conducted an equivalence test to test our first hypothesis (Tolerability). This test was paired with a standard null-hypothesis test (NHST) to determine if VIMS scores changed from baseline. The NHST found no significant effect of the VR experience on VIMS ($t(60) = 0.00$, $p = 1.00$). The observed effect size was negligible, indicating no detectable change in motion sickness (d = 0.00, 95% CI [-0.51, 0.51]). The equivalence test, using an SESOI of 0.35, was technically inconclusive ($t(60) = -0.97$, $p = 0.168$) because our 95% CI [-0.51, 0.51] was wider than these bounds. To summarize, while the VR experience produced no statistically significant change in VIMS, our study seemed to lack statistical precision to formally declare that the effect is statistically equivalent to zero.

To test whether VR exposure influenced attitudes, a Chi-squared goodness-of-fit analysis was conducted. Due to low baseline cell frequency in the "Agree" category ($n < 5$), a Monte Carlo simulation with 1,000,000 iterations was used (Hope, 1968). The results revealed a significant shift in attitude frequencies following the intervention ($\chi2 = 13.23$, $p = 0.009$).

Comparisons of the frequency of participants' responses pre- and post-intervention indicated that attitudes tended to shift in a positive direction. This shift was driven primarily by a large decrease in "Neutral" responses, which fell from 62.9% pre-intervention (39/62) to 21.0% post-intervention (13/62). "Disagree" responses showed a small decrease from 11.3% pre-intervention (7/62) to 8.1% post-intervention (5/62). Correspondingly, "Agree" responses increased from 25.8% pre-intervention (16/62) to 71.0% post-intervention (44/62).

A multiple regression with 10,000 bootstrapped samples did not provide support for our hypotheses that study condition and prior technology experience predict attitude change (*Supplemental Figure 2*). Consistent with this, we did not

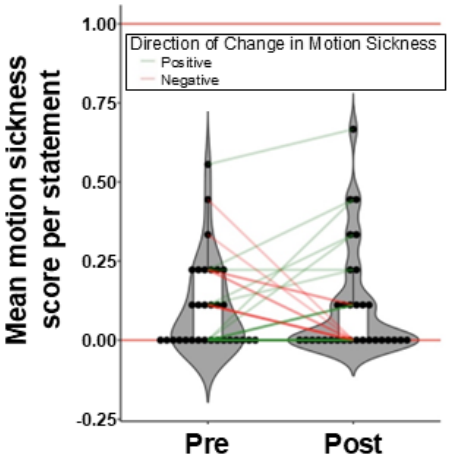



*Figure 2. Mean motion sickness score per statement pre- and post-first-person virtual reality intervention. Violin plots containing box plots indicating participants' pre-intervention (Median = 0.00, Interquartile Range = 0.22) and post-intervention (Median = 0.00, Interquartile Range = 0.11) mean scores per motion sickness statement. Each data point represents a participant's mean score per statement, and the points are connected to illustrate each participant's change in motion sickness. Data points that are connected by a green (light grey) line indicate an increase or no change in symptoms, and data points that are connected by a red (dark grey) line indicate a decrease in symptoms. The red (dark grey) horizontal line at y = 0 denotes the score at which participants reported experiencing no symptoms of motion sickness, and the red (dark grey) line at y = 1 denotes the score at which participants reported mild symptoms of motion sickness.*

observe a statistically significant difference in attitude change between intervention groups ($t(60) = -1.01$, $p = 0.275$). We therefore formally tested for equivalence in attitude change between the groups. The equivalence test (using a SESOI of 0.58, representing a 0.5-point Likert scale change) was significant ($t(60) = 2.09$, $p = 0.02$), suggesting that the two conditions are statistically equivalent in their effect on attitude change. A SESOI of 0.50 has been identified in health research as a benchmark for the smallest effect that would be worth examining (Norman et al., 2003). Since the conditions were statistically equivalent using a higher SESOI (0.58), the difference in effect sizes for the two study conditions is not clinically meaningful. The result of the equivalence test is congruent with the results of the multiple regression, which suggested that the study condition did not predict the change in participants' attitudes towards VR.

A linear regression confirmed a statistically significant negative correlation coefficient of -1.98 ($t(29) = -2.35$, $p = 0.03$) between motion sickness and attitude change (*Supplemental Figure 3*). An exploratory analysis on the effect of gender on attitude change was inconclusive, but quantitatively, women showed larger effect sizes than men [across both conditions, women: $d = 1.38$, 95% CI [0.85, 1.90]); men: $d = 0.68$, 95% CI [0.11, 1.25]). Pre-intervention attitude scores between men ($M = 3.60$, $SD = 1.09$) and women ($M = 3.51$, $SD = 0.59$) did not show a statistically significant difference, $t(35.55) = 0.38$, $p = .71$ (Welch two-sample t-test). See *Supplemental Note 5* for details on the results of these analyses.

## Discussion

### Hypothesis 1 - Tolerability

Consistent with Hypothesis 1, participants reported no significant VIMS ($d = 0.00$), supporting previous work that showed older adults tolerate task-based VR well (Jochmann et al., 2025). Despite the high proportion of women-identifying participants (71%), a group typically more susceptible to VIMS (Stanney et al., 2020), symptoms were negligible. These results support the feasibility of equitable, unsupervised VR telerehabilitation for rural populations with limited clinical access.

Most VR participants reported no motion sickness symptoms (58.1%), with all reporting scores below the "mild" symptom threshold of 1. This high tolerability supports VR's feasibility for home-based rehabilitation in rural settings. Further, low reported VIMS across genders suggests that immersive interventions could improve treatment adherence and help assuage existing gender-based treatment (and recovery) disparities.

### Hypothesis 2 - Acceptability

Hypothesis 2 was supported: VR exposure significantly improved rural older adult attitudes towards VR. While congruent with studies in urban settings (Dockx et al., 2017; Huygelier et al., 2019; Syed-Abdul et al., 2019), our findings uniquely show that positive shifts in attitude occur regardless of delivery method (informational vs. experiential). Since technology acceptance models identify initial attitudes as a prerequisite for adoption (Yang et al., 2025), a simple informational handout offers a scalable pathway for equitable implementation, overcoming the structural and digital access barriers inherent in rural settings.

### Secondary Hypothesis 1 – Comparison of interventions

Secondary Hypothesis 1 was not supported; actively engaging with VR did not significantly outperform the handout ($t(60) = -1.01$, $p = 0.275$), though the VR condition showed a larger effect size ($d = 1.37$ vs. $d = 0.73$). The handout's efficacy likely stemmed from its use of plain language, relatable applications, and a peer testimonial,

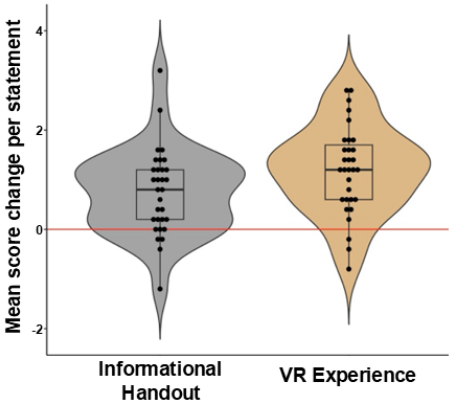



*Figure 3. Mean attitude change per statement across study conditions. Violin plots containing box plots indicating participants' mean score change per statement in the information (box lines indicate Median = 0.80, Interquartile Range = 1.00) and first-person virtual reality (Median = 1.20, Interquartile Range = 1.10) conditions. The dark grey violin plot depicts the information condition, and the tan (light grey) violin plot depicts the first-person VR condition. The red (dark grey) horizontal line at y = 0 indicates no attitude change.*

which directly addressed common adoption barriers such as technology anxiety and social isolation (Cajita et al., 2018; Heinz et al., 2013). External factors likely influenced some of the observed attitudinal shifts. The study lead's clinical background and warm demeanor likely fostered social connection, which has been shown to improve perceptions of healthcare technology (Heinz et al., 2013; Howe et al., 2019). Furthermore, demand characteristics may have played a role; participants were aware the study aimed to develop rehabilitation tools, potentially leading them to provide more favorable responses (Nichols & Maner, 2008; Orne, 1962). These effects may be compounded by self-selection bias, as participants recruited from local markets and adult education programs likely entered the lab with higher "digital readiness" and openness to research than the broader rural older adult population (Wong et al., 2023). Future studies should utilize blind examiners and broader community-based sampling to mitigate these biases.

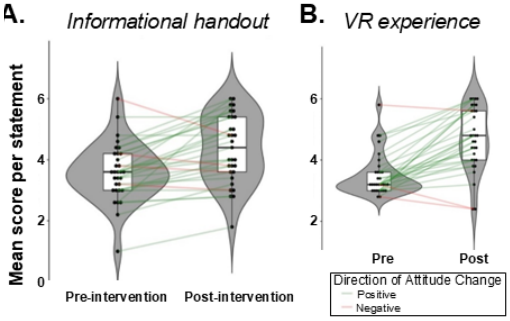



*Figure 4. Mean attitude score per statement pre- and post-information by condition. Violin plots containing box plots indicating participants' pre-intervention and post-intervention average scores per statement for the two different conditions: A. Informational handout, B. VR experience. Each data point represents a participant's average score per statement, and the points are connected to illustrate each participant's attitude change. Data points that are connected by a green (light grey) line indicate a positive attitude change, and data points that are connected by a red (dark grey) line indicate a negative attitude change.*

Regardless, the results suggest that if VR is introduced to rural, older adults in a warm, knowledgeable manner, they may gain a more positive view of the technology. This is significant because if VR is adopted in rehabilitation or other health contexts, clinicians could provide patients with a pamphlet on VR instead of guiding them through a 15-minute VR session and still elicit a positive attitude change.

Rural clinics facing constraints in staff time, clinical space, and digital infrastructure, alongside additional VR-specific technical barriers (Levac et al., 2016; Ogourtsova et al., 2019; Peral-Gómez et al., 2020), can use scalable informational materials to achieve attitudinal benefits comparable to supervised demonstrations. Disseminating these informational handouts through primary care offices, senior living facilities, and senior community hubs can prime acceptance within a patient's local environment. For clinical deployment, we propose a 'graded exposure' model:

*1. Information.* Providers first distribute plain-language handouts to address safety, purpose, and value.

*2. Guided session.* Apprehensive patients follow up with a brief, supervised VR session to build self-efficacy.

*3. Take-home.* Patients transition to low-cost, unsupervised VR sessions for home-based rehabilitation.

This tiered approach maximizes resource efficiency by reserving involved demonstrations for those who require them, providing a low-friction pathway for rural seniors to overcome initial technological anxiety.

**Secondary Hypothesis 2 – Association between technology experience and intervention effect**

Secondary Hypothesis 2, that prior experience with technology would predict attitude change,

was not supported; participants benefited similarly regardless of prior experience. While digital literacy is often cited as a barrier to technology uptake by older adults (Cajita et al., 2018; Standen et al., 2015; Warland et al., 2019), our results indicate that brief exposure can mitigate this hurdle. This suggests that rurality, which is associated with lower digital literacy, does not necessarily disadvantage older adults' responsiveness to technology priming.

Self-selection may partly explain why participants showed a positive attitude change regardless of their prior technology experience. Although 84% of our study participants had no prior VR experience, their voluntary participation suggests an inherent "openness" that may have affected reported attitudes. Additionally, the study's clinical framing likely increased the overall "perceived usefulness" with the structured exposure increasing the "perceived ease of use", two key components of the TAM (Yang et al., 2025) that have been shown to positively influence older adults' intent to use technology, and thus their attitudes towards technology (Dequanter et al., 2022; Martín-García et al., 2022; Zhang, 2023). These factors could have overrode the influence of prior technology experience on shifting attitudes.

**Exploratory analyses**

While a study-level meta-analysis of health technology acceptance found that gender ratios of samples across studies did not significantly moderate the relationship between perceived usefulness and intention to use (Yang et al., 2025), our individual-level exploratory results suggest that women experienced larger attitude shifts than men across both interventions. This suggests women may be more receptive to VR adoption, especially since no baseline differences in initial VR attitudes were found. The contrast with the prior meta-analysis (Yang et al., 2025) may reflect our specific rural sample, where gendered digital readiness could be distinct.

Crucially, the informational handout was as effective as immersive VR exposure for shifting attitudes. However, the first-person VR condition's 71.0% women identification may have contributed to the differences in effect sizes that we observed in the two study conditions. Given that women face systemic barriers to utilizing traditional rehabilitation resources and appointments (Heart & Stroke, 2018), their responsiveness to a low-resource VR priming suggests a potential pathway for improving access using technology-enabled low-cost telerehabilitation.

Finally, we observed that motion sickness symptoms were negatively correlated with attitude change. Since VIMS remains a primary barrier to uptake, future research should investigate predictors of susceptibility and mitigation strategies to ensure VR can become a broadly accessible clinical tool.

**Limitations**

Two main limitations should be noted. First, there was a difference in duration between the first-person VR (28 minutes) and the informational (14 minutes) conditions. Despite efforts to balance this with trivia questions on the handout, this difference introduced potential confounds, including increased social desirability bias in the VR demonstration condition from longer researcher interaction or, conversely, participant fatigue. Second, self-selection bias likely affected our results. Participants recruited through community exercise and continuing education programs were likely inherently more open to research and technology, which could be reflected in more positive attitudes reported. Thus, our findings may not generalize to older adults with significant technology aversion or those less engaged in community activities.

## Conclusions

This feasibility study provides two key insights for the implementation of VR in rural, older adult populations. First, task-based, immersive VR with hand tracking is highly tolerable. Negligible VIMS symptoms, even among a majority women-identifying sample traditionally at higher risk (Stanney et al., 2020), allay safety concerns regarding widespread low-cost immersive VR adoption in rural settings. Second, brief, low-resource interventions effectively improve VR attitudes. The finding that a simple informational handout matches the efficacy of direct VR exposure suggests a scalable, cost-effective method to engage potential rural users of VR health technology. For an apprehensive patient recovering from orthopedic surgery, for example, a handout provides a powerful first step to encourage adoption of VR rehabilitation technology.

Three key future research directions should be explored to better inform VR acceptance in rural older adults. First, the connection between attitude change and behavior change must be established; it remains unclear what magnitude of attitude change is required before participants follow-through on their intent to use VR. Future research should incorporate longer-term behavioral metrics to characterize this relationship. Second, additional research is needed to investigate how gender predicts differences in attitude change and VIMS to determine if historical gender disparities persist with the latest VR technology.

Finally, while these results are promising among healthy rural older adults, generalizability to clinical populations, including those with motor and/or cognitive impairments, must be established. Determining how specific groups, such as stroke or orthopedic patients, receive these interventions is essential for optimizing VR health technology to ultimately improve rural health outcomes, social engagement, and quality of life.

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**Author Roles**
S. Fox played a lead role in data curation, formal analysis, investigation, validation, visualization, and writing – original draft, an equal role in conceptualization and methodology, and a supporting role in funding acquisition. A. Fisk played a lead role in software, and a supporting role in conceptualization, investigation and methodology. D. Blustein played a lead role in funding acquisition, project administration, resources, supervision and writing – review and editing, and an equal role in conceptualization and methodology.

**Disclosure statement**
The authors report there are no competing interests to declare.

**Data availability statement**
All study data, code, and a description of the code and research materials are available at https://osf.io/zk769/.

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**Supplemental Note 1 – Methods details**

*Power analysis*

An a priori power analysis was conducted using G*Power (Faul et al., 2007; Faul et al., 2009) to determine the number of participants required for the study. A linear multiple regression model was used with an effect size of $f2 = 0.25$, $\alpha = 0.05$, and 95% power. An $f2$ value of 0.25 was selected as $f2 = 0.25$ was defined by Cohen (1977) as a medium effect size. Based on previous literature, we expected the first-person VR condition to be superior to the information condition in terms of positively changing attitudes (Noble et al., 2022). Therefore, we decided that we wanted sufficient power to be able to detect a medium effect. Based on the power analysis, it was determined that 55 participants would be required to detect a true effect 95% of the time.

*Randomization procedure*

Random assignment was achieved using block stratification in R Studio (R Core Team, 2023), with each block consisting of six random assignments. The study lead generated the assignment sequence, and potential experimenter bias was reduced as participant assignment was only completed when each study participant arrived at the laboratory. Experimental manipulations were delivered by lab members who had training with VR systems, as well as a bachelor's degree in psychology or computer science (or were in the process of obtaining their degree). The data of two participants were excluded from analysis due to technical difficulties during their study sessions resulting in incomplete data (see *Supplemental Note 4* for more details).

*Recruitment procedure*

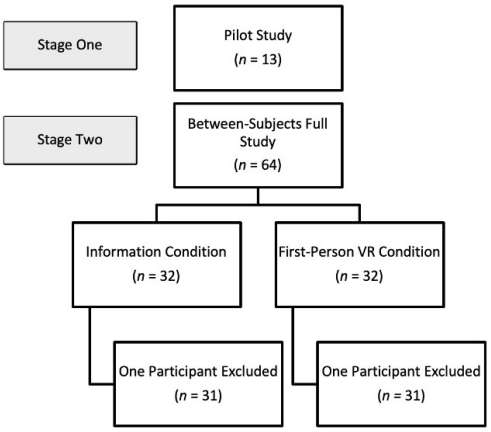
Exclusion criteria for the study included cognitive deficiencies leading to the inability to follow instructions, and the following medical conditions: Macular Degeneration, epilepsy, balance issues, and any neurological condition including stroke, Parkinson's, and dementia. The study lead recruited and enrolled participants through local community groups, yet snowball sampling was the primary recruitment method for the study. There may have been a self-selection bias in our participant pool as participants who were not comfortable using technology likely did not volunteer to participate in the study. This should be considered when interpreting our results.

*Pilot study*

Prior to launching the study, we conducted a pilot study with 13 participants. Eleven participants were assigned to the first-person VR condition, and 2 participants were assigned to the information condition. Participants were not equally assigned to the conditions as the pilot analysis served primarily to determine whether functions of the VR headset, such as voice commands and navigation options, worked smoothly. Feedback from participants was used to improve the clarity of the first-person VR condition. Changes were made to the tutorials provided by the virtual coach in the VR environment, and navigation buttons were adjusted to have a darker backdrop to enhance visibility. Following the implementation of these improvements, we began recruiting participants for the full study.

*Technology experience score*

Participants answered two questions on the pre-intervention survey to assess their experience with technology. The first question inquired as to their prior experience using VR and was scored on a 3-point Likert scale ("Never" = 0, "Once or Twice" = 1, "More than Twice" = 2). The second question asked participants to rate their agreement on a 7-point Likert scale, ranging from "Strongly Disagree" (0) to "Strongly Agree" (6), with the statement "I am very comfortable using technology (e.g., cellphones, computers, gaming systems)". A normalized average transformation was applied to each of the two questions so the indicators would be on the same scale. The two adjusted scores were averaged to create a tech-




*Supplemental Figure 1. The flow of participants through the study.*

nology index score, which ranged from 0 to 1. Since these values were not normally distributed, the index scores were then mean-centered.

**Supplemental Note 2 – VRSQ and other data collected**

While we used the 4-point Likert scale from the original VRSQ, we used the terminology of "None", "Mild", "Moderate", and "Severe" to classify the rating of symptoms to participants. Mean pre- and post-intervention scores were calculated by summing the scores and dividing them by nine. The mean pre-intervention score per participant was then subtracted from the mean post-intervention score. These mean change scores were summed to create an average change in VIMS index.

Movement data were collected from participants in the first-person VR condition by using the controller-free hand tracking feature of the Meta Quest 2. Participants in the first-person VR condition also completed several questions from the Intrinsic Motivation Inventory (IMI; Ryan, 1982) and all study participants had the option to include a reflection on their VR experience at the end of the post-intervention survey. These data are not reported in this paper.

**Supplemental Note 3 – Detailed analytic plan**

Once data collection was completed, the demographics of our sample (i.e., age, sex, prior VR experience) were explored. In addition, effect sizes were calculated for the observed attitude change for the overall study, as well as in the information and first-person VR conditions. A Chi-squared goodness of fit test was then conducted using the R programming language to investigate our primary hypothesis that exposure to VR would positively influence participants' attitudes towards VR.

The null hypothesis was that participants would have the same frequency of "Disagree", "Neutral" and "Agree" responses before the intervention compared to after the intervention. "Disagree" was conceptualized as a response of "Strongly Disagree", "Moderately Disagree", or "Disagree", and "Neutral" was conceptualized as a response of "Neutral/I Don't Know". "Agree" was conceptualized as a response of "Strongly Agree", "Moderately Agree", or "Agree".

Following the Chi-squared analysis, we used a multiple regression with 10,000 bootstrapped

***Supplemental Table 1.*** *Statements used to assess attitudes towards virtual reality*

| Statement Number | Statement |
|---|---|
| 1 | I am open to adopting and using VR in the future |
| 2 | If I had access to a VR system, then I would want to use it |
| 3 | Based on what I know right now, I would recommend the use of VR to friends and acquaintances |
| 4 | I think that virtual reality systems are easy to use |
| 5 | Using a VR system would make me nervous |

*Note*. VR = Virtual reality. Before and after the intervention, participants rated their agreement with the five statements on a 7-point Likert scale, ranging from "Strongly Disagree" (0) to "Strongly Agree" (6). These statements were used to gauge participants' attitudes towards VR before the study. The fifth statement was reverse-scored, such that a statement of "Strongly Agree" was scored 0 points, and a statement of "Strongly Disagree" was scored 6 points. Internal consistency of responses across the five statements was determined to be good ($\omega$ total = 0.91). Scores on the five statements were summed and divided by five. A mean change score was calculated for each participant by subtracting the average pre-intervention score from the average post-intervention score. This average change score was used to assess participants' average attitude change per VR statement after participating in the study.

***Supplemental Table 2.*** *Demographic characteristics of study participants*

| Participant Demographics | *n* | Percentage (%) |
|---|---|---|
| Overall (*n* = 62) | | |
| Women | 36 | 58.1% |
| Men | 26 | 41.9% |
| Average Age | 71.3 | |
| No Prior VR Experience | 52 | 83.9% |
| Information Condition (*n* = 31) | | |
| Women | 14 | 45.2% |
| Men | 17 | 54.8% |
| Average Age | 71.2 | |
| No Prior VR Experience | 25 | 80.7% |
| First-Person VR Condition (*n* = 31) | | |
| Women | 22 | 71.0% |
| Men | 9 | 29.0% |
| Average Age | 71.3 | |
| No Prior VR Experience | 27 | 87.1% |

*Note*. VR = Virtual reality.

samples to determine whether participants' study condition or their prior experience with technology predicted their attitude change. For this model, the dependent variable was the average attitude change per statement, and the independent variables were study condition and prior technology experience. To enhance the interpretability of the model, the technology experience index was mean-centered. The technology experience score was converted to a categorical variable with three levels: "Inexperienced", "Moderately Experienced", and "Experienced". The categories were created by separating the spread of participants' mean-centered responses into three approximately equal groups. It should be noted that one participant completed a post-intervention survey that did not include a "Moderately Agree" option for attitudes towards VR statements on the post-survey. We decided to bias this participant's response against our hypothesis by correcting their pre-intervention survey response from "Moderately Agree" to "Strongly Agree".

We explored Cook's distance values to determine whether there were any outliers in our data. Three participants in the first-person VR condition were identified as being potential outliers based on an inspection of plots, and the criteria that a data point has a large extent of influence over the model if its Cook's distance value exceeds 4/n (Altman & Krzywinski, 2016). The multiple regression model was then run with and without these high influence data points, and the exclusion of these data points had no significant impact on the outcome of the analysis. Therefore, we decided to include these three participants in our data analyses despite their large Cook's distance values.

We then conducted an equivalence test to determine whether the first-person VR condition was more or less effective than the information condition for changing attitudes towards VR. For this analysis, it was determined that the smallest effect size of interest (SESOI) was 0.58, based on a mean attitude change of 0.5 Likert scale points per statement. This value was selected as we were interested in seeing if the difference in VR exposure could cause even a slight shift of half a rating point on each attitude statement. A slight change of attitude could create enough openness to using VR that a participant may consider using it again.

Next, an equivalence test was used to determine whether participants' VIMS was significantly different after the first-person VR experience compared to before the first-person VR experience. For this analysis, it was determined that the SESOI was 3.16, based on a mean motion sickness score change of 0.5 Likert scale points. This value was chosen since ideally we would like for participants to not experience motion sickness when they use our VR system. Therefore, a score indicating mild-to-nonexistent symptoms of motion sickness would be acceptable.

Lastly, our exploratory analysis of the role of gender in attitude change was investigated by comparing the effect sizes of attitude change for women and men in both study conditions. We also explored the relationship between motion sickness and attitude change by using linear regression.

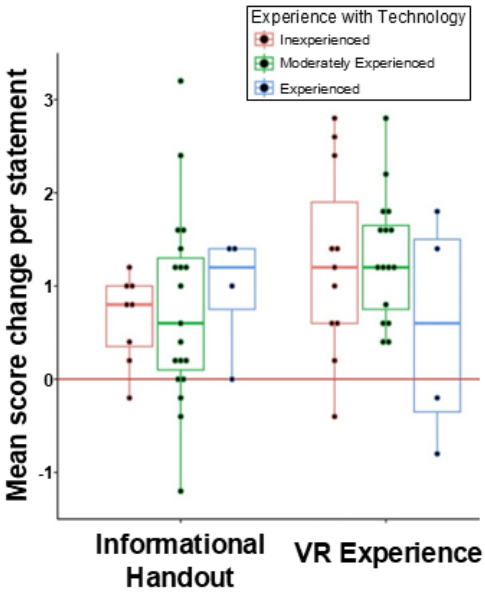
**Supplemental Note 4 – Exclusion of data from two participants**

The data from one participant in the information condition were removed as their survey responses did not save due to wireless network connectivity issues. The data from one participant in the first-person VR condition were also removed as the VR system needed to be restarted halfway through their study session. Restarting the program provided the participant with additional exposure to VR, and they no longer met the criteria of having a single exposure to our VR technology. Accordingly, the data of 62 rural, older adults were included in our final analyses.

**Supplemental Note 5 – Detailed results explanation**

*Secondary Hypotheses 1 and 2*

The first secondary hypothesis that we assessed was whether the study condition was a predictor of attitude change, such that the first-person VR condition was more effective for changing attitudes than the information condition. The second hypothesis that we assessed was whether prior technology experience predicted attitude change, such that participants with less technology experience were more likely to experience greater attitude change than experienced participants.




*Supplemental Figure 2. Mean attitude change per statement across study conditions and prior technology experience. Box plots indicating participants' mean score change per statement in both study conditions, based on participants' self-identified prior experience with technology. Participants in the information condition who identified as being inexperienced (Median = 0.80, Interquartile Range = 0.60), moderately experienced (Median = 0.80, Interquartile Range = 1.10), or experienced (Median = 1.20, Interquartile Range = 0.55) with technology generally had positive attitude changes. Participants in the first-person virtual reality condition who identified as being inexperienced (Median = 0.60, Interquartile Range = 1.10), moderately experienced (Median = 0.80, Interquartile Range = 0.50), or experienced (Median = 0.60, Interquartile Range = 1.85) with technology also generally had positive attitude changes. The red (dark grey) box plots depict the inexperienced technology user subgroup, the green (grey) box plots depict the moderately experienced technology user subgroup, and the blue (light grey) box plots depict the experienced technology user subgroup. The red (dark grey) horizontal line at y = 0 indicates no attitude change.*

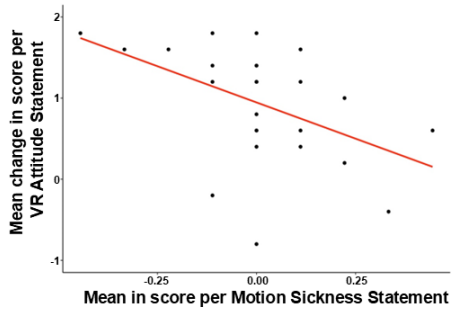
Bootstrapping was used for the multiple regression analysis as the data did not follow a normal distribution. Participants' study condition (levels: information, first-person VR) and their mean-centered technology experience index score (levels: "Inexperienced", "Moderately Experienced", Experienced") were the predictors in the model, and participants' mean attitude change per VR statement was the dependent variable. Being in the first-person VR condition (b = 0.44, SE = 0.22, 95% Bca CI [-0.01, 0.84]), being an experienced technology user (b = -0.29, SE = 0.40, 95% Bca CI [-1.21, 0.38]), and being an inexperienced technology user (b = -0.07, SE = 0.23, 95% Bca CI [-0.52, 0.37]) were not significant predictors of attitude changes towards VR. However, the intercept of the model was significant (b = 0.82, SE = 0.20, 95% Bca CI [0.45, 1.25]). This suggests that when participants are in the information condition and are moderately experienced with technology, their attitudes towards VR will shift positively by an average of 0.82 points per statement. The results of the multiple regression do not provide support for our hypotheses that study condition and prior technology experience predict attitude change (*Supplemental Figure 2*).

To examine whether there was equivalence in participant attitude change between the study conditions, we conducted an equivalence test. Using a SESOI of 0.58, the results of our test were inconclusive. We could not reject the null hypothesis that there is no effect between groups ($t(60) = -1.92$, $p = 0.06$). However, we could not reject the possibility that there is a meaningfully difference in effect size between the two conditions ($t(60) = 0.63$, $p = 0.27$). The result of the equivalence test is congruent with the results of the multiple regression, which suggested that study condition did not predict the change in participants' attitudes towards VR, though the mean in the VR experience condition was larger (1.19 per statement score increase compared to 0.76 for the information group).

*Hypothesis 1 (Tolerability)*

We conducted an additional equivalence test to investigate the hypothesis that participants in the first-person VR condition would not experience a significant increase in VIMS during their VR experience. Using a SESOI of 3.16, we could not reject the null hypothesis that there was no effect of VIMS during the first-person VR experience ($t(60) = 0.00$, $p = 1.00$). Crucially, the results of the equivalence test were significant ($t(60) = -78.46$, $p > 0.001$), which indicates that motion sickness scores following exposure to first-person VR were equivalent to motion sickness scores prior to using VR.

A linear regression confirmed a statistically significant relationship between change in motion sickness in the first-person VR condition and attitude change ($F(1,29) = 5.54$, $R2 = 0.13$). A coefficient of -1.98 ($t(29) = -2.35$, $p = 0.03$) indicates a statistically significant negative correlation between motion sickness and attitude change (*Supplemental Figure 3*). More specifically, for every one unit increase in average motion sickness score per statement, there was predicted to be a 1.98 unit decrease in average attitude change score per VR statement.




*Supplemental Figure 3. Mean change per virtual reality attitude statement and mean change per motion sickness statement. The red diagonal line represents the regression line for the model.*

*Exploratory analyses*

We used an "Exploring Small" framework (Sakaluk, 2016) to investigate whether gender could influence attitudes towards VR. Since we were underpowered for a formal analysis, we examined the effect sizes of the attitude changes for men and women in both study conditions. Across the two study conditions, women had a large effect size for attitude change (d = 1.38, 95% CI [0.85, 1.90]), whereas men had a medium effect size for attitude change (d = 0.68, 95% CI [0.11, 1.25]). Women also had large effect sizes for attitude change in the information condition (d = 1.11, 95% CI [0.28, 1.95]) and in the first-person VR condition (d = 1.53, 95% CI [0.84, 2.22]). In comparison, the effect sizes for attitude changes that men experienced in the information condition (d = 0.52, 95% CI [-0.19, 1.23]) and in the first-person VR condition (d = 1.01, 95% CI [-0.05, 2.07]) contained a value of 0 in their confidence intervals. It is possible that the effect sizes for men in both study conditions were marginal or nonexistent, but the presence of medium and large effect sizes suggests that these results could be due to having a small sample size.

*Supplemental Appendix A. The informational handout that was used in the information condition*

## Virtual Reality (VR) FAQ

***What is Virtual Reality?***

Virtual reality, or VR, is a type of technology. When you put on a VR headset you will become immersed in a virtual space and have a virtual body.



*Image courtesy of Dr. Samiya Khan*

***How do I Move?***

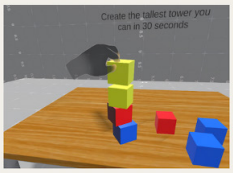
Your virtual body will move just like your physical body. Cameras within the VR headset will track the movements of your hands and show your movements in the virtual space.

***Who is VR for?***

Everyone! VR offers a wide range of virtual spaces and since the technology is easy to use, everyone can find something to enjoy.

***What can I do with VR?***

Many different things! You can play games, practice tasks, explore far away places, exercise, and communicate with friends.




**"I thought that VR was for my grandkids. I never thought about how I could use VR too!" - Sophia, age 86**

A study participant

***What are the Benefits of Using VR?***

VR allows people to engage with entertaining environments, while playing games, being physically active, and making social connections.

## Let's Try Some Trivia!

***Q1. Which of the following are examples of VR in action?***

A) A teenager playing a video game in VR
B) A grandma having a video chat with her grandchildren who live far away
C) An adult exploring far away places virtually
D) All of the above

***Q2. True or False: My movements in VR do not affect what I see through the headset.***

A) True
B) False

***Q3. What technology do you need in order to use VR?***

A) Controllers
B) A TV
C) A VR headset
D) A computer

***Q4. True or False: Only teenagers like VR.***

A) True
B) False

***Q5. Fill in the Blanks: VR systems are _____ to use devices that have _____ use(s).***

A) Difficult, many
B) Difficult, one
C) Easy, many
D) Easy, one

***Answers***

Q1. D) All of the above
Q2. B) False! Cameras detect your movements which are used to move a virtual body that you see through the headset.
Q3. C) A VR headset: Newer VR systems only require you to have a VR headset in order to use VR. However, some systems do use controllers to allow users to interact with the virtual world in different ways.
Q4. B) False! People of all ages enjoy VR.
Q5. C) Easy, many: VR is fairly intuitive to use, and can serve a variety of purposes.