Who Controls VR? A Thematic Synthesis of Studies That Directly Investigated Input Modality with Older Adults

Samuel Chovanec[1], Lora Appel[2,3], Vannawongpaisan Varissara[1], Pál Tamás Szabó[1], Beáta Sosity[1] & Ágnes Bakk[1]

[1]Future Care Lab, Moholy-Nagy University of Art and Design, Zugligeti út 9, Budapest, Hungary | [2]School of Health Policy and Management, York University, 165 Campus Walk, North York, Canada | [3]OpenLab, KITE, University Health Network, 489 College Street, Toronto, Canada

[1]chovanec.sam@mome.hu

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Abstract

Input modality, how users physically control and navigate virtual reality (VR), is largely treated as a secondary consideration in VR research involving older adults. In a broader scoping review of 349 studies, only six (fewer than 2%) were identified as explicitly investigating input modalities. This thematic synthesis of those studies indicates that embodied and familiar interaction techniques are consistently preferred and better tolerated by older adults. The findings further suggest that limited adoption is driven more by issues of acceptance than by inherent incapacity. Conventional handheld controllers appear poorly suited to this population, whereas alternatives such as cycling-based input, hand tracking, and augmented gaze demonstrate greater accessibility. These results highlight the need to position input modality as a central research focus in the accessibility, design and evaluation of VR interventions for older adults.

1. Introduction

Virtual reality (VR) has seen substantial growth as a tool for health interventions with older adults, with applications spanning physical rehabilitation, cognitive training, and social engagement. Despite this growing body of work, a fundamental question has received surprisingly little attention: how do older adults actually interact with these systems? The input modality, the physical means through which a user controls and navigates a VR environment, is typically treated as a background condition rather than a distinct research variable. The dominant VR input devices, handheld motion controllers with multiple buttons, triggers, thumbsticks, and trackpads, were developed by and for the gaming industry, optimized for younger, digitally fluent users with good manual dexterity and prior controller experience (Cook et al., 2019). Older adults have often been excluded from the participatory design of VR technologies, meaning their specific interaction needs have rarely shaped how these systems are built (Seifert & Schlomann, 2021). Boot et al. (2025) make this concrete in their framework for designing extended reality for older adults: successful technology requires matching system demands to user capabilities across motor, cognitive, and perceptual dimensions. When developers do not consider older adults' needs and abilities, the resulting mismatch is not evidence of older adults' incapacity but of technology's misfit (Boot et al., 2025).

As part of a larger scoping review of input modalities in immersive VR used with older adults (N=349) (Chovanec et al., 2025), we identified studies that explicitly investigated input modality as a central research focus.

Of 349 papers included, only six met this criterion. That figure is itself a notable finding. In a field where VR is increasingly deployed with older and potentially vulnerable populations, fewer than 2% of studies were identified as directly examining these systems. This paper reports a focused analysis of those six studies. Given that input modality constitutes the primary point of contact between user and system, its design has implications beyond usability alone. As the studies reviewed here suggest, poorly aligned input mechanisms can compromise safety, increase cybersickness, and ultimately undermine the therapeutic or health goals that VR interventions aim to achieve.

Accordingly, this paper addresses the following research question: **What insights about interaction design for older adults emerge from the limited body of research that directly investigates VR input modality?** To answer this, we examine three related sub-questions: (1) What methodological approaches characterize this body of work? (2) What types of input modalities are investigated? and (3) What findings are reported regarding usability, preference, and interaction outcomes?

2. Method

This paper reports a secondary analysis derived from a broader scoping review conducted in accordance with PRISMA-ScR guidelines (Tricco et al., 2018). Seven databases (PubMed, ACM Digital Library, IEEE Xplore, Google Scholar, Springer, Scopus, and OpenAlex) were searched in April 2025, yielding 4,682 records. Following duplicate removal, screening was supported by ASReview active learning software. Both title/abstract and full-text screening were conducted by SC and VV, with disagreements resolved through discussion among all authors. A total of 721 papers progressed to full-text assessment, of which 349 met the eligibility criteria for the main review. Studies were eligible if they employed head-mounted display (HMD) VR with adults aged 60 years and older.

Data charting was completed by all authors using a piloted form that was refined through calibration sessions. As part of this process, studies were flagged when input modality constituted a central research focus, defined as research explicitly designed to investigate, compare, or evaluate how older adults interact with VR through a specific input modality. Input modality refers to the physical technique or device through which users control and navigate the VR environment. Identification was embedded within the main review process: studies were flagged during charting when input modality appeared to be the primary object of investigation rather than an incidental characteristic of the experimental apparatus. Flagged studies were subsequently reassessed against the above criterion to establish the corpus for the present synthesis.

Studies with three or fewer participants were excluded. Such studies typically represent single-case reports or small feasibility series and do not provide sufficiently replicated evidence for synthesis of interaction outcomes across input modalities. One study that otherwise met the inclusion criterion for input-modality-focused research was excluded on this basis (Chirico et al., 2020). Six studies met the final eligibility criteria. A thematic synthesis was conducted following Thomas & Harden (2008), using NVivo 15. Analysis proceeded in three stages: (1) line-by-line coding of

findings, (2) development of descriptive themes, and (3) generation of higher-order analytical themes capturing recurring patterns across studies.

3. Results

3.1. Study Design

Across these six studies, sample sizes were generally small, ranging from ten to twenty participants. The body of work is methodologically diverse, consisting of two qualitative evaluations (Coldham & Cook, 2017; Shah et al., 2022), two experimental studies (Chen et al., 2024; De'Sperati et al., 2023), one comparative study (Cook et al., 2019) and one usability study (Ribeiro et al., 2024). Direct comparisons across multiple input modalities remain exceptionally rare. Two studies utilized comparator arms (for comparing different levels of gain of the input (De'Sperati et al., 2023) or different tasks (Ribeiro et al., 2024)). Only one study in the corpus compared three inputs simultaneously (Chen et al., 2024), and none of the six compared four or more . In some evaluations, such as those examining direct hand manipulation (Shah et al., 2022), authors claimed comparison with controllers but provided no comparative data. Regarding user-centred design, only half of these studies (3/6) sought first-person feedback directly through quotes, ratings, and observations (Chen et al., 2024; Coldham & Cook, 2017; Shah et al., 2022), but none of the six employed formal participatory or co-design methods. Consistent with the critique by Seifert and Schlomann (2021), the lack of participatory design may reflect a broader orientation that treats older adults as passive recipients of technology rather than active users whose specific interaction needs should shape how these systems are built.

3.2. Types of Input Modalities

Beyond built-in head tracking that is universally present in HMD-based VR and was utilized across all six studies, the included studies investigated four specific alternative input modalities: i) conventional handheld controllers (5/6) (Chen et al., 2024; Coldham & Cook, 2017; Cook et al., 2019; Ribeiro et al., 2024; Shah et al., 2022), ii) cycling-based locomotion (2/6) (Chen et al., 2024; De'Sperati et al., 2023), iii) augmented gaze (enhanced head rotation) (1/6) (De'Sperati et al., 2023), and iv) direct hand manipulation (hand tracking) (1/6) (Shah et al., 2022).

3.3. Usability, Preference, and Interaction Outcomes

Physical challenges (mentioned in 5/6 studies) included high demands on thumb dexterity, grip, as well as difficulty operating closely spaced and uniform buttons (Cook et al., 2019). Additionally, physical constraints such as neck pain and other motor limitations (De'Sperati et al., 2023; Ribeiro et al., 2024), fear of electrocution from cables (Coldham & Cook, 2017), and the smooth material of the controller casing being perceived as fragile (Coldham & Cook, 2017), all generated user hesitancy. Cognitive barriers (mentioned in 5/6 studies) reported that participants frequently forgot button functions mid-task (Coldham & Cook, 2017), pressed the incorrect button (Chen et al., 2024; Ribeiro et al., 2024), found controllers too complex (Chen et al., 2024; Shah et al., 2022) and reported that managing the controller distracted from their engagement with the VR environment (Chen et al., 2024; Coldham & Cook, 2017). Furthermore, controller use, particularly continuous turning, was directly linked to motion sickness (Chen et al., 2024).

In contrast, embodied and familiar alternative inputs yielded substantially better usability and preference outcomes. For instance, cycling-based locomotion produced significantly higher spatial orientation accuracy compared to a handheld controller and promoted active environmental

exploration, making it strongly preferred by older adults due to its physical engagement, perceived safety, and familiarity (Chen et al., 2024). To address physical constraints like neck pain, augmented gaze introduced software amplification of head rotation, which reduced necessary physical head movement by 18% while increasing visual exploration by 46%, successfully accommodating even the oldest-old and non-self-sufficient users without inducing cybersickness (De'Sperati et al., 2023). Furthermore, direct hand manipulation through hand tracking was found to be easier, less demanding, and more stimulating than using conventional controllers. The absence of physical hardware removed a major source of hesitancy, and the natural finger and wrist movements offered the added benefit of incidental exercise for users with reduced hand strength (Shah et al., 2022).

4. Discussion

The synthesized findings reveal a fundamental insight regarding interaction design: barriers to VR adoption among older adults are predominantly behavioural, not functional. The literature frequently relies on a "digital divide" framing that positions older adults as deficient or incapable users (Seifert & Schlomann, 2021). However, the sources demonstrate that older adults are not uniformly unable to use controllers; rather, they are often unwilling due to a mismatch between the technology's design and their needs. Hesitancy around cables, fear of breaking fragile equipment, reluctance to perform uncomfortable head and neck movements, and avoidance of inputs associated with dizziness represent acceptance failures rather than a lack of capacity. Ultimately, the problem to be solved is not older adults' incapacity but technology's misfit with their needs and capabilities (Boot et al., 2025; Chen et al., 2024). This is a distinction that older adults themselves appear to recognize, as they consistently report more positive than negative attitudes toward technologies they actually use (Mitzner et al., 2010).

To overcome these barriers, embodied familiarity emerges as the most practically useful design criterion. Inputs that map onto pre-existing physical experience and existing motor schemas, such as pedalling a bike, natural hand gestures, or looking around, are consistently preferred, better tolerated, and result in superior performance compared to inputs that require learning entirely new operational schemas. These principles translate into several specific design recommendations. For conventional controllers, designers should reduce button count, standardize spacing, differentiate button textures for tactile identification, and address smooth casing materials that generate fragility concerns (Coldham & Cook, 2017; Cook et al., 2019). It is also recommended to separate movement and turning across left and right controllers; Chen et al. (2024) identified 10 km/h forward speed and 10 degrees per second turning speed as ideally suited to older adults. For cycling, applications should use handlebar rotation for steering and entirely disable backward motion (Chen et al., 2024). For head-based input, augmented gaze can be added to any HMD application as a low-cost accessibility option (De'Sperati et al., 2023). Across all recommendations, multimodal combinations of embodied locomotion and gaze or gesture interaction, were identified as the most promising direction (Chen et al., 2024).

Although the six studies yielded consistent and actionable findings, the evidence base remains small. Direct comparison between multiple input modalities were rare, representing a key gap for future research, and several themes relied on single studies, including augmented gaze (De'Sperati et al., 2023) and hand tracking (Shah et al., 2022). The synthesis was restricted to studies in which input modality was the primary research focus. Consequently input-related observations

reported incidentally in the wider corpus were not included and may qualify the conclusions presented here. Nevertheless, the small number of eligible studies is itself noteworthy: only six of 349 studies (<2%) explicitly and systematically investigated input modality in older adults' VR use beyond single-case reports. Because these studies were identified through a secondary analysis of a larger scoping review, some papers addressing input more implicitly may not have been captured. Findings from the broader corpus will be reported in the full scoping review.

5. Conclusion

Much VR research with older adults has focused on whether they can use the technology, treating them as recipients of fixed systems rather than active participants whose interactions must be designed for. This synthesis suggests that commonly used input paradigms, particularly hand-held controllers, are often poorly aligned with the physical and cognitive characteristics of older adults, while more embodied and familiar alternatives show promise despite limited evidence. Importantly, difficulties with VR interaction appear to arise less from incapacity and more from issues of acceptance and design fit. Advancing VR as a viable health technology for older adults therefore requires a shift in research priorities: input modality should be treated as a core design and evaluation consideration, with systematic comparisons of alternative approaches and the active involvement of older adults in the design of interaction techniques.

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