

Sensors in Inclusive Virtual Reality Games for People with Intellectual Disability

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Abstract. People with intellectual disability are often neglected in the design of emerging technologies, such as virtual reality (VR). This qualitative study, in the form of an exploratory experiment, investigated how VR gaming experiences can be designed using various sensors to be more inclusive for people with intellectual disabilities (ID). Data was collected through observation and semi-structured interviews with a VR game prototype. Six participants ($n = 6$), all of whom were staff working with individuals with disabilities, took part in the study. The findings suggest that VR controllers, when designed to replicate simple, concrete, and repeatable patterns, were well-received. Joystick had mixed results and were considered less intuitive due to design choices, but could still contribute to inclusive VR environments. Voice (not speech) control was the most promising option, with room for improvement in terms of accuracy and response time. An important conclusion is that the design of VR headsets should be improved to reduce the feeling of confinement and enhance accessibility. Finally, the study emphasizes the importance of integrating input methods early in the design process to create more inclusive experiences.

Keywords: virtual reality, intellectual disability, game development, gaming experience, accessibility

1 Introduction

Virtual reality (VR) has evolved from its early applications in healthcare and education during the 1990s to become a mainstream medium for entertainment, training and social interaction. However, despite advances in hardware and software, VR game experiences often overlook the needs of adults with intellectual disabilities (ID), who may struggle with complex sensor-based interactions. The problem this study addresses is the lack of explicit knowledge on how VR games can be adapted to improve inclusion and accessibility for users with ID; in particular, we ask: how can different sensor input methods in VR be designed to create more inclusive gaming experiences for this population?

Existing accessibility guidelines rarely address VR's unique combination of motion tracking, gaze detection, and controller or voice input. Miranda-Duro et al. [1] found that fewer than 10% of commercial VR titles meet basic accessibility criteria; Heilemann et al. [2] highlight fragmented recommendations

that fail to cover sensor-based controls. Additionally, Reski and Alissandrakis [9] demonstrated that input modalities, ranging from standard hand controllers to gaze interfaces, can significantly affect usability for individuals with cognitive or motor limitations. Broader critiques emphasize that assistive technology is often an afterthought in design rather than being integral to the process [3, 4].

In VR, "sensors" refer to any hardware or software that detects user actions, whether physical movements, button presses, or voice commands, and translates them into in-game responses. These sensors can either create barriers or open up new avenues for interaction. For example, finely tuned motion controllers may overwhelm users with limited dexterity; well-designed voice or gaze controls could provide more intuitive alternatives. Early discussions with disability support staff confirmed a stark disparity: although video game titles exist for children with ID, few are accessible or specifically tailored to adults in this demographic.

People with ID often face challenges in abstract reasoning, memory, and task sequencing [5], underscoring the need for interfaces that emphasize simplicity, repetition, and clear feedback. Prior work has examined sensor accuracy, such as gaze-tracking latency, and its impact on usability [6, 7]; yet little research explores how these technical parameters intersect with the lived experiences of adults with ID in VR contexts.

2 Methods

This study employed an exploratory experimental design, combining observation with semi-structured interviews. Participants were purposefully selected, focusing on professional caregivers and support staff rather than individuals with intellectual disabilities (ID). While observation is an inclusive method [8] that could be used to involve people with ID, the selected approach minimized ethical risks and addressed challenges such as communication barriers and cognitive limitations in the target group. A VR prototype was developed in two iterations to assess user interaction and apply theoretical insights. Data collection included concurrent think-aloud observation of day activity center staff (DAC, a facility governed by Sweden's LSS Act) to capture real-time user thoughts. Semi-structured interviews complemented this approach, providing deeper insights. This was a pragmatic approach where validity was considered as far as possible from staff close to, rather than directly from, people with ID. Furthermore, to enhance reliability, structured protocols and interview guides were used. Recordings were transcribed and coded, and inductive thematic analysis was applied to identify codes, categories and themes.

The study examined the usability and accessibility of different input methods for VR gaming, focusing on their suitability for individuals with intellectual disabilities. Six staff members ($n = 6$) from DACs participated in testing three input methods: VR controllers, a joystick with an additional button, and voice control. DACs are providing work-like activities for adults with ID (and often other disabilities, such as autism) to participate voluntarily, who are far from

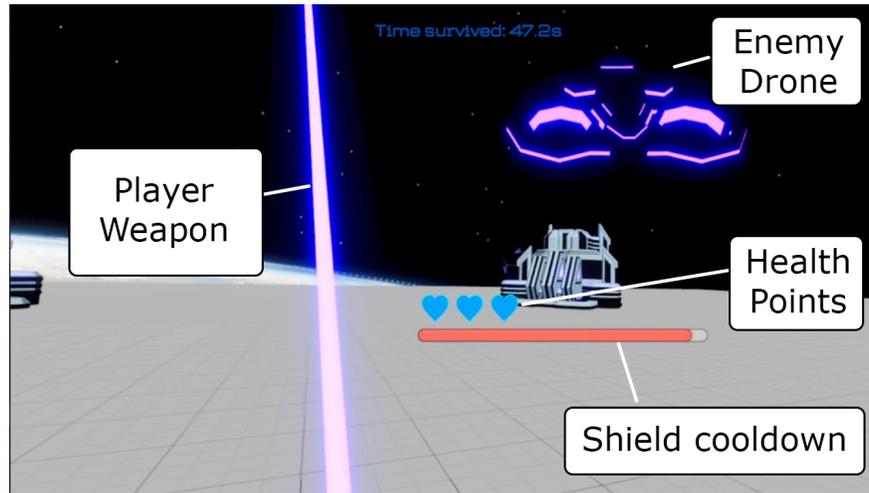


Fig. 1. Screenshot of the VR prototype showing the player’s beam saber and an enemy drone. The interface displays the health points and the shield cooldown.

the job market and are not engaged in education. For analysis and reporting, staff members were anonymized and referred to using the codes P1 through P6.

3 Results

The results from this study were summarized in a set of themes (and categories), as follows: 1) Inclusive game experience for adults with ID (VR controller immersion, Joystick immersion, Voice immersion, Audiovisual immersion); 2) Accessibility and challenges for adults with ID (VR controller ergonomics, Joystick ergonomics, Voice ergonomics, Game mechanics, and Learning); 3) Suggestions for improvements (Language and instructions, More functionality, Dynamic game design).

Table 1: Thematic analysis

Theme: Inclusive game experience for adults with ID	
Category	Code
VR controller immersion	Sense of immersion with VR controllers. Felt easier to handle. Felt sensitive and responsive. Felt intuitive. Fun to use.
Joystick immersion	Bulky and difficult to use. Joystick response was less natural, especially for sword movement.

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	Joystick mode felt less engaging. Risk of becoming monotonous.
Voice immersion	Easy to use but not as enjoyable. Voice command delay broke immersion. Voice input felt repetitive and monotonous.
Audiovisual immersion	Sci-fi theme was exciting and fitting. Dark theme helped highlight the sword. Sounds and vibrations enhanced immersion.
Theme: Accessibility and challenges for adults with ID	
Category	Code
VR controller ergonomics	Easier to understand and use for people with ID. Appreciated for mimicking real-life movements. Requires less physical effort.
Joystick ergonomics	Requires less physical movement. Hard to use both hands simultaneously. Challenging to manage multiple functions. May be easier for some, but less stimulating. Takes time to get used to.
Voice ergonomics	Can be frustrating if not responsive. Requires precise language, which may be hard for users with ID. Lack of feedback increases difficulty.
Game mechanics and learning	Challenging but not overwhelming. Tutorial was clear and helpful. Important to offer options for diverse needs. Reasonably difficult for most users.
Headset ergonomics	Headsets may feel confining or uncomfortable. Users with ID may need more time to learn the controls.
Theme: Suggestions for improvements	
Category	Code
Language and instructions	Important to have the game in Swedish, especially for users with ID. Need for simple and clear instructions. Staff should receive setup guidance.
More functionality	Ability to pause the game is needed. Voice commands could activate based on sound level. Ability to skip parts of the tutorial. Customizable sound effects. More visual aids to support understanding. Clearer visual effects like making the shield more visible.

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Dynamic game design	Simpler versions with fewer enemies or more lives could increase accessibility. More variety in environments would improve engagement.
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From this thematic analysis, the most important results were that VR controllers need to be designed to replicate simple, concrete, and repeatable patterns, to be accessible for the target group with ID. It was also found that joysticks had mixed results, such as not being as intuitive and easy to use in VR. Voice control (pitch and volume but not words or speech commands) was the most promising option, with room for improvement in terms of accuracy and response time.

3.1 Controller Immersion

All participants described the VR controllers as intuitive and well-suited for users with ID, primarily due to their alignment with natural hand movements and the minimal physical effort required to interact with the game. The controls were experienced as simple yet engaging, with several participants (P1, P2, P4, P6) emphasizing that the controllers made the experience fun and accessible. For these users, the immersive quality of swinging a virtual object and receiving immediate feedback through vibrations and in-game responses helped reinforce the feeling of control and enjoyment. One participant noted that VR controls would likely be easier for someone with ID to manage compared to other input methods, while another highlighted their intuitive nature as a key strength. Others (P3, P5) acknowledged the simplicity of the interaction, though with slightly less enthusiasm and cautioned that adding more buttons or functions could risk reducing accessibility for the target group.

Participants generally found the joystick less intuitive and harder to use compared to the VR controller. Five out of six (P1, P2, P3, P4, P6) described it as clunky or awkward, especially when simultaneous input (button + joystick) was required. They noted that this complexity could be particularly difficult for users with ID, as it demands fine motor coordination and the ability to multitask. The overall impression was that joystick-based input may create confusion and frustration, especially in fast-paced or precision-based tasks.

Participants had varied perceptions of the immersive potential of voice input. For some (P2, P6), the voice control system provided a novel and engaging experience, particularly due to its hands-free nature, which contrasts with conventional physical input methods. The method was described as accessible and intuitive, especially for users who may have difficulties handling controllers. However, other participants (P1, P4, P6) noted that the repetitive nature of using voice, particularly when the system lacked consistent responsiveness, could become tedious and potentially reduce user engagement over time. These insights indicate that while voice input can enhance immersion through minimal effort

and novelty, its repetitive structure and dependence on technical reliability may limit its long-term appeal.

3.2 Controller Ergonomics

Participants generally perceived the VR controllers as ergonomically accessible, with a gameplay difficulty that was considered appropriate and well-balanced. The controllers were described as easy to operate, offering a level of challenge that was stimulating yet not excessive. Both P1 and P2 highlighted this equilibrium, noting that the interaction was neither too complex nor too simplistic. However, P2 also suggested that while the controls were manageable for them personally, individuals with ID might require additional support to navigate certain tasks. P3 noted that although some aspects of the interaction were straightforward, situations involving multiple simultaneous actions could increase cognitive load. To enhance accessibility for users with ID, P3 recommended clearer instructions and the incorporation of pauses between interactive elements, allowing for reflection and comprehension.

Participants generally perceived the joystick as more complex to use, particularly due to the need to coordinate both hands simultaneously. This complexity raised concerns about its suitability for individuals with ID. Several participants (P1, P3, P4, P5) noted that using a joystick in combination with a button press could be cognitively or motorically demanding, especially when actions had to be synchronized. While the joystick was described as manageable when limited to a single large button and a simple motion, additional complexity could quickly become overwhelming. One participant (P6) pointed out that despite these challenges, some individuals with ID might still find the joystick suitable, depending on personal abilities and preferences.

Voice control was widely regarded as a promising alternative for users with ID, primarily because it removes the need for fine motor skills or coordinated physical actions. Participants (P2, P5) observed that pitch- and volume-based voice input could be more intuitive than standard button-based systems, particularly for users who struggle with traditional interfaces. However, the effectiveness of this method was strongly linked to its responsiveness. Several participants (P1, P3, P6) described how minor delays or inconsistent feedback led to confusion and disengagement, especially when users were unsure whether their input had been registered. These findings underline that while voice input holds ergonomic advantages, its accessibility depends on real-time feedback and system precision to prevent user frustration and maintain clarity.

In addition to input methods, some participants raised concerns regarding the usability and comfort of the VR headset itself, which also includes displays for visual output. P3 specifically highlighted that the physical experience of wearing the headset could be a barrier for individuals with ID. The feeling of being enclosed or the unfamiliarity of the device might cause discomfort or hesitation. This discomfort, in turn, could discourage users from engaging with the technology or make it more difficult for them to focus on the experience. P3 em-

phasized the importance of preparatory routines and gradual exposure to help users become familiar with the headset before gameplay.

4 Discussion

The staff expressed a positive experience of the VR controllers, as being natural, responsive, precise and intuitive, analogue to actual body motion and voice, with a direct link between cause and effect, which is a typical good design for the target group. This can be contrasted with [9] who could not find significant differences between different input methods; however, their study did not include disabled people. Similarly, [10] found that immersion was not necessarily better in VR compared to PC desktop environments, also without considering people with ID for whom immersion may be even more crucial. The staff also expressed that VR controllers required guidance and time to be useful, as it is a new type of interaction for this group, supported also by [11]. Further issues were also discussed regarding joysticks and voice input.

5 Conclusion for the AT field

Based upon the discussion of the results and related research, it can be concluded that the design of VR headsets may need to be improved to reduce the feeling of confinement, enhance accessibility and inclusion for the target group. Furthermore, a tentative VR design guideline for people with ID can be defined as: Replicate actual motion or voice patterns that the person with ID can perform. This requires the patterns to be concrete, easy to understand and repeat, and provide direct cause and effect between the actual and virtual worlds. Finally, the study emphasizes the importance of integrating input methods early in the design process to create more inclusive experiences.

While this study provides important information based on the delimitation of views from staff with experience working with the target group, there is a need for more participatory research directly with the target group. However, such research still needs the participation of staff to ease communication with researchers and support persons in the target group based on their individual needs.

Future research suggestions include a more direct user-centric study with participatory design, preferably involving a diversity of users with different needs, and examining more variables to provide a clearer picture of whether different input methods can be useful. Further research should also take into account the ethical and practical challenges experienced by this target group by developing different methods that allow participation on their own terms. Small-scale design workshops with visualizations and qualitative experiments with observation [8] are probably possible, as such research can be done individually and without requiring participant abilities such as speech and imagining abstract concepts of sensors and virtual reality. Conducting large, quantitative studies to enable generalizable results is a methodological challenge with this target group, as they

have challenges participating in larger groups, in unfamiliar environments such as labs, or answering to surveys with texts and abstract concepts.

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