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Virtual reality gaming in rehabilitation after stroke – user experiences and perceptions

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ABSTRACT

Purpose: The present study explored participants' experiences with and perceptions of using fully immersive head-mounted virtual reality (VR) gaming as rehabilitation after stroke.
Methods: Four men and three women (median age 64 years) with chronic stroke and varying motor impairment (mild to severe) were interviewed after 10 weeks of VR training on the commercial HTC Vive system, focusing on the upper extremities. Inductive qualitative thematic analysis was performed.
Results: The analysis revealed three main themes: playing the game, benefits and effects, and personalizing the game. Playing the game encompasses both the feeling of being immersed in the game and descriptions of the gaming being motivating and fun. Benefits and effects describe the participants' expectations of potential benefits, the importance of getting feed-back, and the impact in daily life. Personalizing the game includes finding the right game and level, and the participants' need for support to achieve full use of the training.
Conclusions: Participants with chronic stroke described the fully immersive VR gaming intervention as a fun and motivating way to improve their functioning in everyday life. Qualitative studies are needed to explore how people with stroke perceive VR gaming when it is implemented in real clinical environments.

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Qualitative research; neurological rehabilitation; stroke; virtual reality; patient preference; qualitative thematic analysis

➤ **CLINICAL IMPLICATIONS**

- VR gaming was perceived as a positive and motivating rehabilitation after stroke.
- Getting feedback and perceiving benefits are essential parts of VR rehabilitation.
- Commercial fully immersive VR-games might be an option for stroke rehabilitation when the game can be personalized and support is available.

Introduction

The development and use of both commercial and custom-made virtual reality (VR)-based gaming has increased significantly in recent years. Evidence indicates that VR gaming could be a valuable addition to standard post-stroke rehabilitation [1–3]. VR applications reportedly create engagement [4] and have led to functional improvements in people with stroke [3,5,6].

VR is a set of computer-produced images and sounds that represent a place or situation in which a person can take part [7]. Within this broad definition, a variety of different technologies have been considered as VR in healthcare settings, including console games, wearable technology, and head-mounted displays [8]. In contrast to commercial systems, which are developed with the aim of entertaining and providing high-quality engagement, the systems and games developed for rehabilitation purposes are usually customized to target the specific needs of a clinical population [9–12]. The gaming industry continues to develop games with various settings and adjustments that, together with lower prices and better technical performance, make commercial games attractive for stroke rehabilitation [6,9]. VR interventions can target many consequences of stroke, including reduced motor function, mobility, postural control, and cognitive impairments [6,13–19]. Importantly, gamification of rehabilitation (i.e. the use of game design in a non-gaming context) may increase motivation, adherence, and training dose among users [4,6]. In addition, exploitation of the neurophysiological reward mechanisms with dopaminergic system engagement can result in increased neural plasticity [20–22].

VR gaming has been demonstrated to be effective as add-on therapy for improving upper limb function in chronic stroke [1,2,6,23,24]. Users have described VR training as motivating and engaging [4,25], and this method appears to be feasible and acceptable for use in rehabilitation [26]. Prior studies have

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Supplemental data for this article can be accessed here.

Figure 1. Participant playing the VR-game Beat Saber.

predominantly evaluated partly immersive console-based gaming or customized serious gaming rather than fully immersive head-mounted commercial off-the-shelf gaming systems [6,27]. Qualitative studies evaluating users' experiences with fully immersive commercial head-mounted VR gaming after stroke are currently lacking. Better knowledge of users' experiences with and perceptions of VR-based gaming will be crucial in guiding clinicians and developers in improving the use of VR in stroke rehabilitation.

In the present study, we explored participants' experiences with and perceptions of using a commercial fully immersive head-mounted VR gaming system as a means of rehabilitation for chronic stroke.

Methods

This qualitative study was part of a larger single-case design study evaluating the effects of VR training on upper extremity functioning [28]. For transparent reporting, we used the Consolidated Criteria for Reporting Qualitative Research (COREQ) [29].

Participants

Participants were recruited through advertisements at patient organizations and support groups. The inclusion criteria were a stroke diagnosis at least 6 months prior and impaired upper extremity function. Exclusion criteria were being diagnosed with any condition other than stroke that affects upper extremity function.

The intervention study included seven participants (four men and three women) with a median age of 64 years (range, 48–74 years). All who participated in the intervention study agreed to participate in an interview after the training period. Six participants had been diagnosed with infarction, and one with hemorrhage, between 6 months to 6 years (median 2 years) prior to enrollment. Upper extremity impairment was severe in two participants, moderate in four participants, and mild in one participant according to Fugl-Meyer Assessment of Upper Extremity [30,31].

One participant exhibited some residual perceptual and cognitive deficits, and two had communication difficulties (slower in speaking). None of the participants had previously used head-mounted VR gaming, but two had previously tried Wii games. The majority of participants had a higher level of education and were Swedish, though other ethnicities were also represented. Demographic and clinical data were obtained within the intervention study protocol through an interview and clinical assessment. All participants provided written informed consent for participation prior to the study, and ethical approval was granted by the Swedish Ethical Review Authority (1075-18).

VR intervention

The VR intervention was offered three times per week for 10 weeks, with sessions lasting approximately 30–45 min. Among the participants, the actual total training time varied from 105–915 min and number of sessions from 4 to 27 [28]. All VR sessions were supervised by a researcher and held at a research facility near a university hospital within an urban area in Sweden. An assessment battery focused on upper extremity function was performed in a repetitive manner before, during, and after the intervention, following a single-case design protocol [28].

Training was performed using a commercial off-the-shelf head-mounted VR system (HTC Vive). This system provides fully immersive virtual 3 D room-scale tracking and interaction with the virtual environment through a headset and haptic hand controls. Each participant was presented with five different games: NVIDA VR funhouse, the Lab, Beat Saber, Climbey and Pierhead Arcade. The rhythm-based game Beat Saber was the most frequently used among all of the participants (Figure 1). In this game, the player holds a lightsaber in each hand and cuts blocks that are presented from different locations to the sound of music. The game difficulty is adjustable across a broad range, from extremely easy to extremely hard, and the volume of the music and special effects could be reduced to some extent to lower the risk of sensory overload. This game did not require the ability to press any buttons, which made it playable by individuals with limited finger movements. The game was designed to be played standing but

Table 1. Example of quotes with associated codes, subthemes and themes.

Quote	Code	Subtheme	Main theme
"Therés no limitation, one uses the whole body"	Moving without limitations	Being immersed in the game	Playing the game
"Games have that ability, to make us all the time want to do a little bit more."	Encouraged to do more	Motivating and fun	
"I would be willing to try anything that could make me better"	Strong wish to improve	Expectations of potential benefits	Benefits and effects
"I've shown my kids and my wife and they don't believe I'm the one standing there waving my arms."	Showing progress to family	Getting feedback	
"During the project I found it easier and easier to empty the dishwasher, fold the laundry, put my hair up for example … "	Easier to do everyday activities	Impact on daily life	
"Beat Saber is … one can adapt the level extremely. Íve used that a lot"	Adjusting the level in the game	Finding the right game and level	Personalizing the game
"I couldn't hold the control myself, I had to put Velcro tape on it, but that worked fine"	Adaptations made it work	Need for support	

could also be played while sitting. During the training, the supervising researcher was close by to determine any potential need for safety precautions.

Data collection

Within a week after the VR intervention period ended, each participant was interviewed individually in a quiet room near the site of the VR training intervention study. The interviewer (EK) was a female occupational therapist with extensive experience in stroke rehabilitation who had not been involved in the assessments or training. Interviews were conducted using a semi-structured interview guide with open-ended questions (see Supplemental Material). The interviews lasted approximately 40–60 min and were audio-recorded and transcribed verbatim. After each interview, the researchers had a meeting to discuss the first impressions gained from the interviews. These reflections were then carried forward in the subsequent interviews and analysis.

Data analysis

The transcribed interviews were analyzed using inductive thematic analysis according to Braun and Clarke [32]. The data were organized and coded using NVivo software 10 (QSR International). After becoming familiar with the data, they were coded line by line and sorted into preliminary themes that were potentially of interest in terms of the study aim [32]. Both the first author (MG) and the interviewer (EK) read all transcripts prior to analysis and were actively involved in the initial coding to ensure accuracy. This process provided an overview of the data and helped to identify how the codes could be merged into themes. The preliminary themes were identified by the first author and discussed and revised subsequently within the larger research group until definition and naming of the final themes was achieved. In this phase, suitable quotations were selected to illustrate the content of each theme [32]. Table 1 presents examples of selected quotes, coding, and themes. The coding was mainly performed by the first author (MG); however, the entire research group participated in regular group discussions before and during the data analysis.

Results

Our analysis identified three main themes: playing the game, benefits and effects, and personalizing the game. The main themes and respective subthemes are summarized in Figure 2. In the results presented below, all participants have been given pseudonyms to ensure anonymity.

Figure 2. Themes and subthemes.

Playing the game

The theme "Playing the game" included two subthemes that reflected the participants' descriptions of feeling fully immersed while paying the game, and that training was fun and motivating.

Being immersed in the game

The feeling of being in another world and separated from reality, as described by the participants, encouraged them to move their body more within the game than they were used to; they perceived that they could reach higher and move faster. Tony (>64 years, >2 years since stroke) stated, *"Wow, it's an amazing feeling to start with,"* and then added, *"The VR environment triggers something up here [in the brain] that you otherwise are not aware of."* Mary (<64 years, <2 years since stroke) said, *"One lifts, moves your arm more, to a higher extent …"*. Hannah (>64 years, >2 years since stroke) added, *"One might do a movement one didn't think to do normally— you want to do it because the block appears up there, oops!"*

The immersive gaming experience was also described as problematic by one participant. Eric (>64 years, >2 years since stroke) described his impression that he was elevated during the game, which was intimidating: "*Once I put the equipment on, I go up … I'm standing on a pedestal … it's quite a lot of meters down and … one loses the balance.*" Another participant concluded that, due to the intense visual and audio impressions in the game, he would not recommend playing early on after stroke and that he would not have managed to do that.

Motivating and fun

While playing, the participants described being focused on achieving rewards within the game. Being able to see one's progress was rewarding and motivating, and reaching the next level in the game created a feeling of accomplishment. Carl (>64 years, <2 years since stroke) offered, "*There is some sort of enjoyment in that. You were able to manage that [level] … and you are, in those worlds, rewarded.*" Eric proudly said, "*I've learnt how to catch … and went from three thousand to thirty thousand (points).*"

The feeling of having fun was described as an important aspect when using the game for a longer time. All participants had experience participating in different rehabilitation interventions, and two participants had even tried Wii games during their post-stroke rehabilitation. However, none of the participants had previously tried head-mounted VR gaming. Compared to conventional rehabilitation, they described VR as being fun and engaging. About his usual rehabilitation, Carl said, "*That kind of rehabilitation is boring, you have to say that… This one on the other hand is fun, that's the difference between these two.*"

Benefits and effects

The theme "Benefits and effects" included three subthemes that reflected the participants' expectations of potential benefits, getting feedback, and perceived impact on daily life. Even when the intervention study was focused on upper extremity function, the participants described their perceived benefits and effects from a broader perspective.

Expectations of potential benefits

The participants had a positive attitude towards the VR training even before trying. They thought that it could be beneficial for their recovery and could be a way to reach their goals. The participants' main expectations were to recover from the stroke, regain mobility and strength, and ultimately return to their life as it was before the stroke. For example, some of the mentioned expectations were returning to work and being able to drive a car. The participants hoped that the VR training would enable them to reach their personal goals.

The participants further expressed that they would be willing to try any kind of rehabilitation intervention that would help their recovery. Hannah noted that "*the interest was raised because it was something new, exciting,*" and that it made her wonder, "*What happens in the brain?*" When asked why she joined the study, Sophia (<64 years, <2 years since stroke) answered, "*Foremost, my big curiosity, well this I must go to!*" Overall, the intervention seemed to meet this expectation, as all of the participants expressed that using the games was fun, modern, and exciting.

Getting feedback

A few of the participants were video-recorded during one of the VR sessions. Watching the recording and seeing oneself in action from the outside provided another perspective for the participants. After seeing the video, Sophia reflected, "*I didn't think my movement pattern was that good until I saw it with my own eyes … so unrestricted.*" Seeing themselves on video made them realize how much more and how much better they could move in the game compared to their perceived ability in everyday life. Some invited family members, friends, or, in one case, a physiotherapist to come and view the session live or to watch the video. Mary described that she had experienced effects since starting the VR training: "*Three months ago, I didn't do half of what I do now … it's not only me that has noticed that, all of my kids have noticed that.*" Getting someone else's view of their performance served as confirmation of the improvements they achieved.

Getting feedback on the performance and results was essential for the participants, not least of all to find the motivation to continue with the training. Carl stated, "*If I had seen any physical changes, I would have come more often, more than I have.*" According to Hannah, "*If I were offered this training in the future, I would like to know the results of this to be motivated to do the next … whether it had shown anything positive.*"

Impact on daily life

Although the intervention focused on upper extremity function, the participants described benefits in other areas. Hannah explained, "*I didn't notice that much improvement in the hands and arms … However, it felt, directly when I left from here, that I had better 'flow' when I walked and that was very noticeable … I thought it was imaginary, but it wasn't.*"

The participants described different activities in everyday life being easier to perform since starting the VR training. This included small things, such as opening a drawer or applying toothpaste on a toothbrush. Others described improvements in their attention, balance, coordination, and quality of life. Mary explained the difference between before and after the study: "*I was in pain on this entire side. I couldn't lift my arm this way. I couldn't sleep. And the more I trained, the pain went away and now I can lay on this side—I can turn.*"

Several of the participants experienced the VR training making them tired, and they had to rest afterwards. Some took a break in the middle of the session until they had the energy to continue, whereas others did not need or take breaks. Hannah said, "*It was very fun, but I was extremely tired afterwards. I went home to sleep several hours … it took a lot of my energy.*" Mary also felt the need to rest afterwards and connected this with the stroke: "*We who have had this [stroke], we get tired very quickly, so I feel tired in the whole body.*" Despite the tiredness the participants were motivated to continue.

Personalizing the game

The theme "Personalizing the game" included two subthemes describing the participants' need for personalized support and adjustments. The participants described finding the right game and game level, and getting help with the game settings and with handling and adjusting the VR equipment as being important.

Finding the right game and level

The participants were offered several different games to try in order to find one that was best suited to their personal rehabilitation needs and preferences. Ultimately, Beat Saber was the most used game—likely because it was easy to play, fun, and offered a large variety of adjustments to meet the player's needs. Hannah stated that it was very important to have the game set to the right level: "*It was set to 'easy' and when we used the next level, it didn't work. They [the bricks] came too fast. Obviously, that was no fun! No! One wants it to work.*"

Beat Saber included rhythm-based music that accompanied the movements, which was described by most of the participants as captivating. However, some participants felt that the musical style did not suit their preferences. Carl described the music as "*lots of beats and such, quite boring, rather same-same.*" Eric also commented that it was not his kind of music: "*The music they presented there was beat-beat … I had to adjust to that.*" They both would have preferred being able to choose their own music in the game.

Two participants raised concerns that all games may not be suitable for everyone because they could contain violence. Mary stated, "*Maybe Swedish women like it, but not foreign women … in their culture, it's 'haram'* [forbidden by God]." Carl said, "*Once, one had a bow and then you were supposed to shoot those … it's not allowed really … to shoot someone to death,*" and he also concluded that playing games like Beat Saber, which has no "enemies", was much better in that regard.

Need for support

In this study, the researcher was present at all times and started the game on the computer, helped the participants put on and adjust the VR glasses and hand controls, and selected and adjusted the games to each participant's needs. For example, Sophia said that sometimes the game had bugs: *"[The researcher] has always been there … one needs someone like [him] … When it comes to computer experience, I'm not experienced enough to resolve a bug in the program*." However, a few participants thought that they could have managed to start up the game by themselves after receiving some guidance.

Some of the participants were unable to hold the control themselves; in these cases, Velcro bands were used to fasten the hand control to the participant's hands. In addition, one of the participants experienced difficulties managing the hand controls due to cognitive decline. The training could be performed either sitting or standing, and the researcher was always standing close by to minimize the risk of falling. These personalized adjustments made it possible for all of the participants to feel safe and to use the equipment and games despite their impairments.

Discussion

The qualitative interviews provided rich data regarding how the VR training was experienced and perceived by the participants with chronic stroke. Analysis of the content of the interviews revealed three main themes: playing the game, which covered the perception of being immersed within the game, as well as perceiving the training to be motivating and fun; benefits and effects, which included the participants' expectations of potential benefits, the perceptions of getting feedback on the results, and the experienced effects on daily life; and personalizing the game, which included the importance of finding the right game and level and the need for support in adjusting the VR equipment to the participant's needs and ability level.

The VR game environment created a feeling of being immersed in another world and separated from reality. This feeling is often described in sports and gaming as "being in the zone" or experiencing a flow, and describes the feeling when a person is completely immersed and focused on what he or she is doing, leaving everything else behind [33]. The fully immersive VR game provided visual feedback through the head-mounted display, which may have increased feelings of immersion and flow. The use of gaming elements has previously been described as contributing to the feeling of flow and to motivate users to continue using VR in post-stroke rehabilitation [34]. Movements in the VR games were perceived as freer and more automatic and spontaneous than real-life movements. Participants reported that the game itself pushed them to move more and described a positive feeling of having a healthy body in the virtual world. This perception can be connected to the experience of flow, in which one may experience a feeling of being strong and capable while being fully focused on an activity [33].

It is crucial not to underestimate the importance of finding rehabilitation methods that are motivating and fun, especially as patients will need rehabilitation and training for many years after stroke [35,36]. Motivation is a key aspect of any training application. The direct feedback from the game itself, in the form of points and levels achieved, was an important feature that motivated the participants, similar to results from other studies [34,37]. The combination of VR training with other types of rehabilitation has been shown to be beneficial and should be considered for people who need long-term rehabilitation [38,39].

Our present results are promising and support the use of VR gaming to complement traditional stroke rehabilitation. The participants in this study perceived improvements in many different aspects of functioning, including balance, pain, arm use in daily activities, and even quality of life. Similarly, a previous study evaluated the experience of using commercial VR gaming and noted a perception of functional gain and improvements in the performance of daily activities [25]. Functional improvement has also been clinically validated in previous studies evaluating the effects of using different VR systems. Data regarding the effects of VR in stroke remain sparse and are difficult to synthesize due to the wide range of VR systems and methods used. Qualitative data can complement the results from quantitative studies [28] and guide researchers and clinicians in selecting appropriate interventions to meet individual needs.

In this study, we evaluated a commercial off-the-shelf VR system (HTC Vive) that is currently accessible at a relatively low cost. Previously, HTC Vive was shown to be feasible for use in rehabilitation because it has a large working area with excellent accuracy [9]. The selected system and games (predominantly Beat Saber) were useful and well-tolerated by the participants with varying levels of impairment in the chronic stage of stroke. These findings support the potential beneficial use of this kind of technology for stroke rehabilitation. VR systems that require customized hardware and/or software [5,13–17,24,27] carry an extensive cost and continuous need for updates and support. In contrast, commercial games, as used in the current study, can be purchased and updated more easily. Unfortunately, despite the wide range of commercial games available, not many are suitable for people with stroke.

Several factors must be considered when incorporating VR gaming into rehabilitation, including the choice of game and available adjustments. It is important to choose wisely and to ensure that adequate adjustments can be made. Some games may contain violence or other features that may be unacceptable or less suitable for some participants. Our present participants found the game Beat Saber to be engaging, and the rhythm-based music provided reinforcement to movements and made the training engaging. However, the participants would not recommend using games with substantial visual or audio input early on after suffering a stroke. In another study of participants with more recent stroke, sensory overload was described due to features in the VR game, resulting in fatigue, dizziness, and sickness [4]. The side effects of cybersickness is considered to be higher in fully immersive head-mounted displays VR games [8]. This suggests that immersive VR gaming may be better suited for long-term stroke rehabilitation rather than rehabilitation in the acute stage.

The participants also highlighted the importance of receiving appropriate support to perform VR training. For example, the game predominantly used in this study (Beat Saber) was fully adjustable in terms of difficulty and sound. In addition, it did not require pushing any buttons during play, and persons with reduced hand function were able to use the hand controls after some adjustments. Although technology is becoming more accessible, there will likely be a need for professionals to adjust the games and to select the most beneficial exercises for each person. A recent study highlighting the safety aspects of using head-mounted displays VR games in post-stroke rehabilitation reported that, due to the need for physical assistance in balance and fall prevention, the applicability in non-supervised settings is still limited [40].

Strengths and limitations

The participants of this study were highly motivated and had actively applied to participate in a VR intervention study, which can be considered as selection bias. This study included all participants who had participated in the VR intervention study. However, the information power was considered to be satisfactory considering the aim of the study, the diversity of the group (stroke consequences, demographic characteristics), and the richness of the data [41]. In particular, the sample included individuals with a wide range of functioning, from severe to mild impairment. The sample also varied in gender, age, and cultural background, though it did not include people with severe cognition or communication impairments. All participants were able to contribute to providing rich data in the interviews and had the capability to reflect on several important aspects regarding the VR training, which strengthens our findings. The VR training was introduced and supervised by a dedicated person with good knowledge of the technology, which may embody possible bias. Thus, further studies are needed to evaluate the feasibility of fully immersive VR training in actual clinical environments.

Conclusions

Participants with chronic stroke described the VR gaming as motivating and experienced a positive feeling of flow that prompted them to move their body more during the sessions. The participants also described perceived improvements in their everyday life activities. The game predominantly used in this study (Beat Saber) was suitable because it offered a wide range of adjustments. Further qualitative studies are needed to explore how people with stroke experience and perceive similar VR interventions when they are implemented in real-life clinical settings.

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Disclosure statement

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