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Co-creating Immersive Virtual Neurorehabilitation Environments: A Participatory Design Workshop

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Abstract. Head-mounted displays can offer personalized immersive virtual reality (VR) training for patients who have suffered an Acquired Brain Injury by tailoring the complexity of visual and auditory stimuli to their cognitive capabilities. However, how these virtual environments should be designed remains undetermined. We conducted a participatory design workshop with eight neurorehabilitation experts to collect their opinions on using immersive VR-based neurorehabilitation and co-create examples of low and high-cognitively demanding immersive virtual training environments. Participants highlighted the importance of developing meaningful and realistic environments. This study provides an example of a high-tech co-creation workshop whose results provide insights into designing training environments in immersive VR to meet patients' needs.

1 Introduction

Participatory design is a research approach that allows the development of products and services that align with the needs and experiences of relevant stakeholders. It comprises the active involvement of those using the product from the early stages of the design process and ensures that their insights and preferences are integral to its development [1]. Stakeholder engagement can lead to a high sense of ownership towards a product and ensure that solutions are inclusive - addressing the diverse needs of different groups - and applicable in the real world.

In neurorehabilitation, the involvement of rehabilitation experts (e.g., occupational therapists and physiotherapists) in the co-creation process is particularly crucial due to the complexity of diseases and the heterogeneity of patients.

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To guarantee that the technical solutions meet each specific person's clinical needs, recovery goals, and cognitive capabilities, rehabilitation experts should engage with developers in co-creation activities as their first-hand experiences with a broad pool of heterogeneous patients can generate unique insights, suggest practical features, identify barriers, and highlight usability issues. These aspects may not be evident to developers, and their implementation can lead to improved recovery outcomes and patient satisfaction [2].

Here, we present the methodology and results from a *participatory design workshop* with eight neurorehabilitation experts to collect their opinions on the use of immersive VR-based neurorehabilitation and co-create examples of low and high-cognitively demanding immersive virtual training environments for Acquired Brain Injury (ABI) patients with different cognitive abilities.

2 Methods

The study was approved by the Human Research Ethics Committee of the Delft University of Technology and the board of directors of Rijndam Revalidatie, Rotterdam, the Netherlands. Eight neurorehabilitation experts from Rijndam (three occupational therapists, three physiotherapists, one psychologist, and one speech therapist) joined the two-hour in-person participatory design workshop. Participants, five females, had an average of 13.1 years (SD = 10.3) of professional experience and from none to intermediate experience with VR. They were equally divided into two groups and each group was assisted by a VR developer.

The workshop consisted of a *focus group* (Activity 1) and an *ideation session* (Activity 2), which were conducted on the same day. We provided each group with post-its and four paper sheets designed by the authors (Fig. 1) and posing specific questions to stimulate reflection and conversation. To help participants empathize with ABI patients, each group received a *Persona,* i.e., a fictional representation of a moderately affected or a severely affected ABI patient [3].

Fig. 1. Participants working on the paper sheet used during the focus group. Post-its placed on top of the paper sheet report participants' ideas.

2.1 Activity 1: Focus Group

The focus group session aimed to prepare participants for the ideation session. Each group had three paper sheets, each with one question, such as assessing the advantages and disadvantages of immersive VR (Q1), exploring its applications in neurorehabilitation (Q2), and identifying factors to consider when developing VR experiences for ABI patients (Q3). Participants were invited to read a question, verbally share their opinions using a think-aloud method [4], write their answers on post-its, and place them on the paper sheet. They had five minutes to answer each question.

2.2 Activity 2: Ideation Session

The ideation session aimed to understand what would make an immersive virtual training environment low- and high-cognitively demanding. We invited groups to create examples of a low- and a high-cognitively demanding virtual environment using a rapid prototyping technique [5].

Each group was assigned an HMD (HTC Vive Pro Eye, HTC Vive, Taiwan & Valve, USA) that allowed participants to experience an immersive virtual environment from a first-person perspective, a monitor to show what they see in the HMD, and a VR developer who implemented desired changes in the virtual environment, e.g., changes in characteristics of objects (e.g., texture fidelity, position, size), or removal/addition of elements (e.g., furniture, sounds, avatars). The provided virtual environment was a replica of a training room at Rijndam, created in the Unity game engine (Unity Technologies, USA - version 2021.3.24f1). To show participants the potential of immersive VR and promote their creativity, we showed six videos of different versions of the same virtual environment with, e.g., fewer objects, different lighting, or different backgrounds, among others.

Each group was asked to reflect on the characteristics of both a low- and a high-cognitively demanding virtual environment by using a paper sheet posing three questions, such as identifying environmental factors affecting task performance (Q1), suggesting adjustments for cognitive demand levels (Q2), and imagining out-of-the-box changes if given the opportunity (Q3). Participants placed post-its with their ideas on a line drawn in the middle of the paper sheet, labeled from low-cognitively demanding on the left to high-cognitively demanding on the right.

Both activities were audio-recorded, and we performed video recordings of the computer monitors during the ideation session.

3 Results

3.1 Activity 1: Focus Group

Participants highlighted that immersive VR offers benefits such as reduced need for therapists, versatility in exercises, and adaptability to patient needs, while they also noted its high cost, potential cognitive challenges, safety concerns, and

issues with excessive use (Q1). They suggested immersive VR therapy should be tailored to individual impairments and simulate real-world environments. They valued immersive VR for its potential as a research tool, exploring possibilities like eye-tracking and visual feedback (Q2). When developing immersive VR for ABI patients, they emphasized creating engaging, adjustable experiences with a focus on safety and appropriate guidance (Q3).

3.2 Activity 2: Ideation Session

Participants agreed that low-cognitively demanding virtual environments should be static and simplified, with minimal distractions, calming colors, and familiar or relaxing sounds to aid patients with reduced cognitive abilities. These environments could include videos with task instructions to enhance comprehension, especially for those with speech difficulties. In contrast, high-cognitively demanding virtual environments should be dynamic, with increased stimuli, bright lights, loud sounds, moving objects, and secondary tasks. Environments that resemble real life, such as kitchens and public spaces, were recommended to facilitate daily life activity training. Both groups emphasized the importance of varying visual, auditory, and cognitive stimuli to create diverse training experiences.

4 Discussion and Conclusion

Co-creating with neurorehabilitation experts resulted in relevant insights for the further development of immersive virtual training environments. Participants highlighted the potential of immersive VR in rehabilitation to reduce the need for therapists, offer versatile exercises, and adapt to patient needs. However, the disadvantages include high costs, potential cognitive challenges, and safety concerns.

Participants suggested that patients with reduced cognitive abilities would benefit from low-cognitively demanding environments that are static and simplified with minimal distractions; for example, one participant said: “the first stage could be where there’s nothing happening around you ..”. For patients with higher cognitive capabilities, participants recommended training in high-cognitively demanding virtual environments that are dynamic and challenging, with the inclusion of varied stimuli and realistic environments: “.. stimuli are all around you .. from multiple sides .. from left and right, increasing the one, reducing the other ..”. Overall, the participatory design workshop resulted in usable insights for VR developers to create immersive VR training environments that accommodate the needs of patients with different cognitive capabilities.

Neurorehabilitation experts recommend therapies and interventions; therefore, their experiences and insights are important when developing new therapeutic solutions. Yet, engaging patients in future research activities is essential to capture their opinions on virtual training environments and further explore the topic of motivation.

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