# Brain-Computer Interfaces and Virtual Reality - a way of immersion[*]

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## Abstract

Brain-Computer Interfaces (BCIs) and Virtual Reality (VR) are two rapidly advancing technologies that are redefining aspects of human-computer interaction. Together, they offer transformative opportunities for creating immersive, thought-controlled environments with meaningful applications across gaming, rehabilitation, psychological therapy, and professional skill enhancement[1, 4]. The integration of these technologies into interactive systems opens up new dimensions for intuitive and accessible user experiences. This paper aims to examine the foundational principles of BCIs and VR, their convergence, and the broader potential of their combined application. In particular, we explore how their fusion can enhance accessibility and provide alternative modes of interaction for individuals with motor impairments or other disabilities.

Our research initiative was inspired by a challenge we encountered as a team during the 2024 Spring School[3] organized by g.tec medical engineering GmbH[2]. We took part in the VIRTUAL BR41N.IO HACKATHON under the open-ended track titled 'Your Hacking Project.' During our brainstorming process, we came across the condition known as Acute Central Cervical Spinal Cord Injury (ACCSCI), a syndrome that, according to Schneider et al.[5], is characterized by disproportionate motor impairment, particularly affecting upper limb mobility. This observation led to the team considering the challenges individuals with ACCSCI face in experiencing the world beyond their immediate physical environment.

Motivated by this, the development of a prototype system that combines a VR

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headset, a BCI headset, voice recognition, artificial intelligence, and the Google Street View API, was proposed, all of these technologies orchestrated within the Unity Game Engine. This integrated platform aims to simulate real-world exploration, allowing users with limited mobility to virtually navigate and experience outdoor environments. By combining these cutting-edge technologies, the solution aspires to provide a sense of agency and connection with the external world for those affected by ACCSCI, bridging the gap between physical limitations and experiential freedom.

The integration of VR and BCI within an application presents a promising framework for providing a naturalistic, user-driven experience. By combining BCI and VR technologies, it explores the potential to allow users to interact with virtual environments through cognitive intent, aspiring to potentially reduce the reliance on traditional input devices. The hypothesis that was proposed is that this synergy could facilitate the progression towards more adaptive, user-centered interfaces responsive to real-time brain signals. Such a system holds the promise of reshaping how users with physical impairments engage with technology, opening up new pathways for inclusion and digital autonomy.

To explore this hypothesis, the team developed a proof-of-concept system in which users can traverse Google Street View using the VR and BCI headsets. The Unity game engine was employed to manage core logic and render panoramic Street View imagery to the VR display. Within the virtual environment, user movement is controlled through SSVEP-based flashing objects that serve as BCI input triggers. Voice input, processed through a HuggingFace speech-to-text model, enables destination selection, allowing users to verbally indicate where they wish to explore. To enhance immersion and engagement, the ChatGPT API generates contextual descriptions and concise, trivia-style insights based on the user's current location.

In order to evaluate the usability and immersive quality of the prototype, the application was tested by five participants. The testing sessions focused on the ease of navigation, responsiveness of the BCI triggers, accuracy of voice input, and the overall user experience in simulated real-world exploration. Feedback indicated that the application successfully provided a sense of presence and control, even in the absence of traditional input devices. Participants reported a high level of engagement and expressed the potential value of such a system for individuals with limited mobility. These preliminary results support the viability of the concept and suggest promising directions for further refinement and user-centered development.

*Keywords:* Brain-Computer Interface, Virtual Reality, EEG, Human-Computer Interaction, HuggingFace, ChatGPT

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