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Collaborative Virtual Reality BCI Post-Stroke Neurorehabilitation Using Head-Mounted Displays

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Introduction: We are thrilled to present our newly developed collaborative Brain-Computer Interface (BCI) and Head-Mounted Display (HMD) system, designed to revolutionize post-stroke neurorehabilitation. In this system, both the post-stroke patient and a healthy therapist enter a shared virtual environment (VE) through their respective avatar representations. This immersive setup enables real-time interaction, allowing the therapist to guide and support the patient in performing rehabilitative tasks. By combining neural signal processing with virtual reality, our collaborative BCI-HMD system fosters motor recovery and cognitive engagement, offering a novel approach to accelerating rehabilitation outcomes and improving quality of life.

Material, Methods and Results: Our collaborative BCI-HMD system builds upon the theoretical framework outlined in [1] and the practical implementation described in [2]. The system combines a collaborative VE developed using the Unity game engine with a BCI that detects the patient's motor imagery intentions. Publicly available OpenViBE™ software for BCI integrates EEG signal acquisition, processing, and classification. A proprietary VE server application facilitates communication between the VEs of the patient and therapist and the OpenViBE™ engine. This setup allows the therapist to control, modify, and pace the neurorehabilitation training, while the patient, through motor imagery (MI) intentions, carries out the designed motor rehabilitation tasks (Fig. 1).

EEG-based control leverages the concept presented at the 17th BCI Meeting [3], with its core element being the tensor decomposition of EEG data. The tensor method extracts subject-specific, spatially, and spectrally constrained EEG oscillations associated with the MI process [4]. Additionally, the system is enhanced with functional electrical stimulation.

We conducted a series of experiments with healthy volunteers and post-stroke patients during the system's development stages, focusing on user acceptability. The results of these experiments will be reported.

Figure 1: *A therapy room showing a standing therapist's avatar on the left and a sitting patient's avatar on the right. A control menu visible to the therapist is displayed on the back wall. The therapist selects, modifies, and paces the task, while the patient controls the avatar's hand movements in a closed BCI loop utilizing recorded EEG. Interaction between the therapist and patient takes place throughout the experiment.*

Conclusion: While we can currently support the validity of the proposed BCI neurorehabilitation system only with partial clinical results, we believe that the collaborative concept between therapist and patient within the BCI-VR environment has the potential to significantly influence wider clinical practice.

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