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Real-Time BCI Control of a Virtual Third Arm

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Introduction: Motor augmentation is a transformative field in neuroscience and robotics, enabling humans to extend their physical capabilities beyond natural anatomical boundaries [1]. This study focuses on the development of a virtual reality (VR) paradigm designed to facilitate the learning processes for controlling a supernumerary effector (SE), a third arm, through an electroencephalography (EEG)-based brain-computer-interface (BCI).

Material, Methods and Results: A VR-based simulator was developed to integrate an EEG-driven BCI for controlling a virtual SE. Seven participants controlled a modified avatar featuring a third arm in a virtual reality environment, performing tasks requiring the use of the SE alongside natural arms (see Fig. 1). The SE's actions - grasping and releasing - were operated using motor imagery (MI), with sensory feedback delivered via a haptic vest to enhance embodiment [2]. EEG signals collected during a motor imagery task were processed using Common Spatial Patterns (CSP) and Linear Discriminant Analysis (LDA) to train a hand state classifier [3]. The classifier achieved an average accuracy of 73% (±4% std) for recognizing hand grasping, and 71% (±5% std) for releasing (Fig. 2). Neural activity patterns during motor imagery exhibited event-related desynchronization in the mu band. Additionally, participants reported high levels of ownership and control over the virtual SE.

Figure 1: *A user interacting with the virtual environment using the modified avatar equipped with a supernumerary effector (SE). The left panel shows an external view of the avatar, and the right panel shows the first-person perspective of the user.*

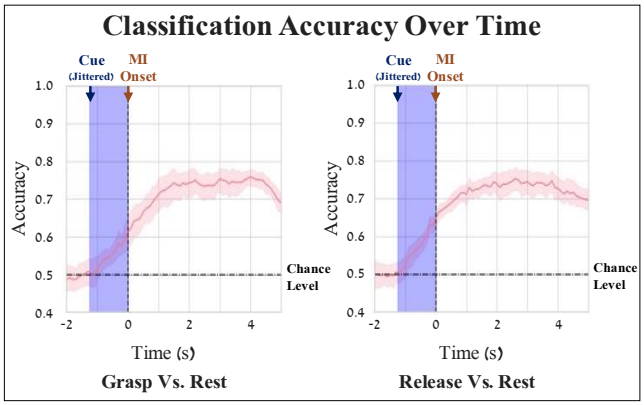

Figure 2: Accuracy of the supernumerary arm actions during the motor imagery task.

Conclusion: This preliminary study validates the feasibility of direct MI BCI-controlled motor augmentation within a VR setting. The findings lay the groundwork for future research into motor augmentation, with potential applications for assistive technologies and rehabilitation.

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