INTEGRATION OF THE BRAIN-COMPUTER INTERFACE AND 3D- EXTENDED REALITY

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INTRODUCTION

Patients with profound physical limitations often face progressive motor decline, communication barriers, and social isolation. Amyotrophic lateral sclerosis (ALS) is approximately 1.6, 0.1, and 2.05 per 100,000 people worldwide, in Canada, and in Alberta, respectively [1]. Median survival and disease progression differ, but most patients experience a steady loss of independence [2]. Emerging technologies such as extended reality (XR) and brain-computer interfaces (BCI) present new opportunities to improve quality of life. By combining immersive environments with neural signal-based control, XR and BCI may enhance social participation, rehabilitation, and communication in individuals with severe motor impairments.

MATERIALS AND METHODS

Two neuroimaging systems, EEG and fNIRS, were compared for controlling a custom-designed 3D VR simulation with fifteen healthy participants. Each participant completed the short version of User Experience Questionnaire (UEQ-S) after two sessions, one with each system. fNIRS data were collected using NIRSport2 with 16 channels over prefrontal and motor areas; hemoglobin and oxyhemoglobin concentrations were calculated using the modified Beer–Lambert law, filtered at 5 Hz, and baseline-corrected with wavelet decomposition before CSP feature extraction. EEG data were acquired using OpenBCI with four electrodes (C3, C5, C2, C4), filtered from 10–50 Hz, and processed with CSP. Features from both systems were classified with LDA. VR interaction in Unity® used Lab Streaming Layer (LSL) for real-time avatar control. Participants collected tokens by moving left or right through brain activity.

RESULTS AND DISCUSSION

Statistical analyses revealed no significant differences between the two systems, with success rates of 47.14% for EEG and 46.07% for fNIRS. UEQ-S responses indicated that the EEG-BCI system was rated as the most comfortable (68.3%), easiest to control (68.3%), and clearest to understand (85.9%). Overall, participants recognized EEG-BCI as more user friendly, noting its adaptability across individuals and greater cost efficiency for long-term use. Although performance scores were slightly higher with the fNIRS-BCI system, most participants preferred EEG-BCI due to its comfort, ease of application, and practicality. Importantly, the Brain–Computer Interface and Extended Reality (BCI-XR) setup achieved 100% feasibility and usability, as all participants were able to use both systems without difficulty. Both EEG and fNIRS integrations ran properly and fulfilled their intended purpose.

Fig 1 Participants in fNIRS (left), EEG (right), and background of the 3D scenario create in Unity®.

CONCLUSIONS

Our system represents a cutting-edge approach with the potential to restore communication with XR systems for individuals with severe physical limitations. The BCI-XR platform has the potential to play a critical role in rehabilitation by providing a virtual environment that supports communication, fosters interaction, and promotes neuroplasticity. This technology may benefit patients with locked-in syndrome, quadriplegia, palsy, post-stroke impairments, ALS, and related conditions. BCI-XR enables patients to reconnect with their loved ones while engaging in meaningful activities. Importantly, the system is user-friendly, low-cost, and adaptable, making it suitable for integration into telehealth and rehabilitation programs, particularly for patients who lack access to conventional therapies.

REFERENCES

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