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AR-Based Mirror therapy and Peripheral Electrical Stimulation Enhance Sensorimotor Integration

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Introduction

Mirror visual feedback (MVF) is a rehabilitation technique that facilitates motor recovery by activating the mirror neuron system, engaging sensorimotor networks, and promoting cortical plasticity. However, conventional mirror therapy is limited by restricted visual perspective and low immersion. Augmented reality (AR) enables spatially aligned, immersive mirror feedback. Peripheral electrical stimulation (PES) enhances cortical excitability via afferent sensory input. This study aimed to investigate whether the combination of AR-based MVF and PES enhances sensorimotor-related cortical activation more than PES alone.

Methods

Twenty healthy right-handed adults participated in this study. An AR-based system was developed to generate virtual bilateral hands spatially aligned with the participants' real upper limbs. A small spherical pinch target was presented randomly at 3–5 second intervals above the virtual right thumb. Participants performed a left-hand thumb–index pinch in response to the visual cue.

Upon accurate detection of the left-hand pinch via motion tracking, the virtual right hand executed the pinch while the virtual left hand remained stationary, providing mirror visual feedback. Simultaneously, the target disappeared, and a 1-second train of PES was delivered to the right forearm at the individual sensory threshold (below motor threshold). In the control condition, an identical amount of PES was delivered without MVF (no mirrored visual movement).

Each participant completed 100 trials per condition in a within-subject design. Conditions were performed in separate blocks with a 5-minute rest interval. EEG signals were recorded using a 17-channel system. Data were band-pass filtered and segmented into epochs from −0.5 to +1.0 seconds relative to pinch onset. Baseline correction was applied using the pre-movement interval. Event-related spectral perturbation analysis was conducted to quantify task-related changes in mu-band power (8–13 Hz) over the C3 electrode, representing the left sensorimotor cortex. Mu rhythm suppression and duration of desynchronization were compared between conditions.

Results

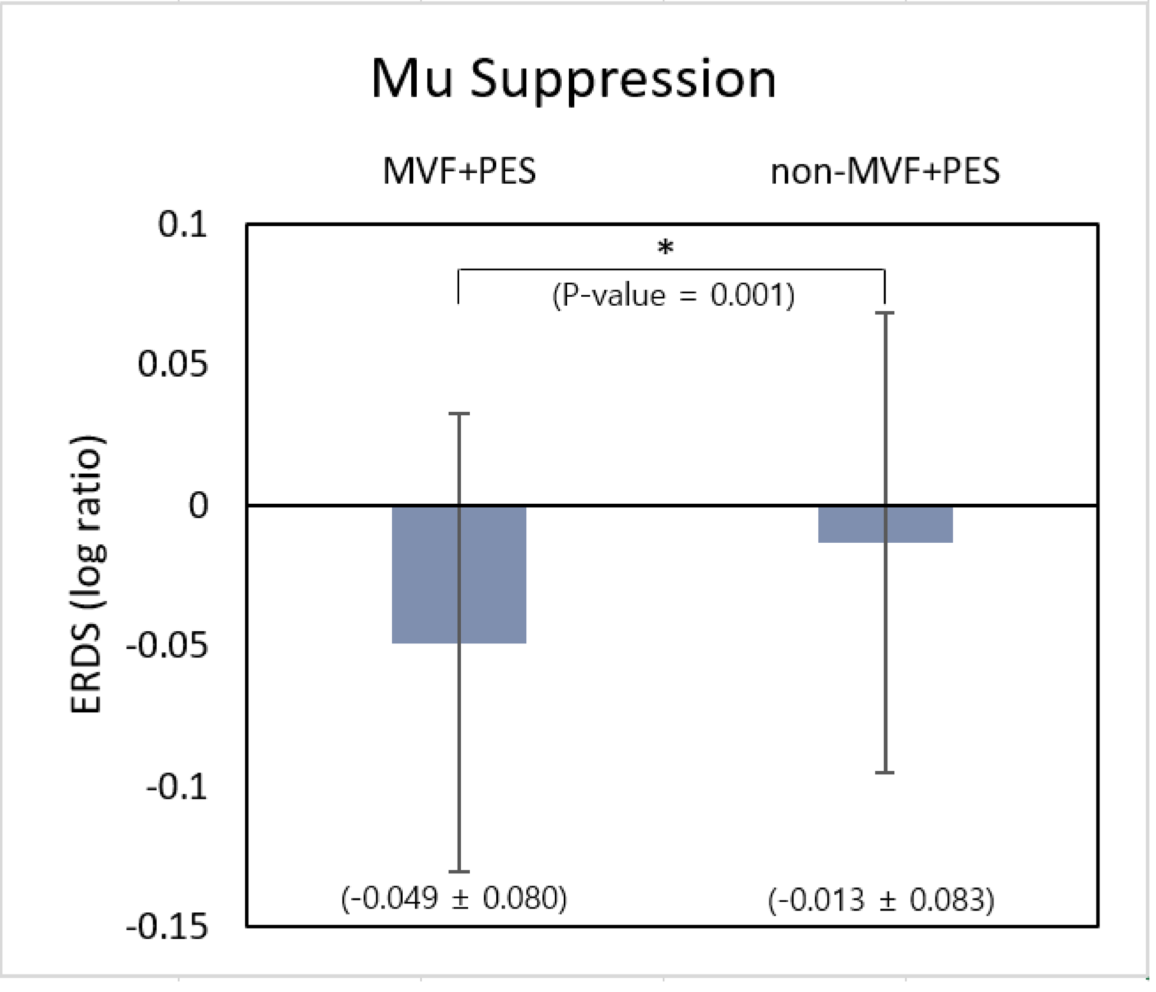

Fig 1. Mu suppression over C3 in both condition

Participants had a mean age of 23.95 ± 4.6 years (9 males, 11 females), with no history of neurological or upper extremity musculoskeletal disorders. In both conditions, significant mu rhythm suppression was observed over the left motor cortex (C3) following left-hand pinch movements. The MVF + PES condition produced greater mu suppression and a prolonged desynchronization duration compared with PES alone.

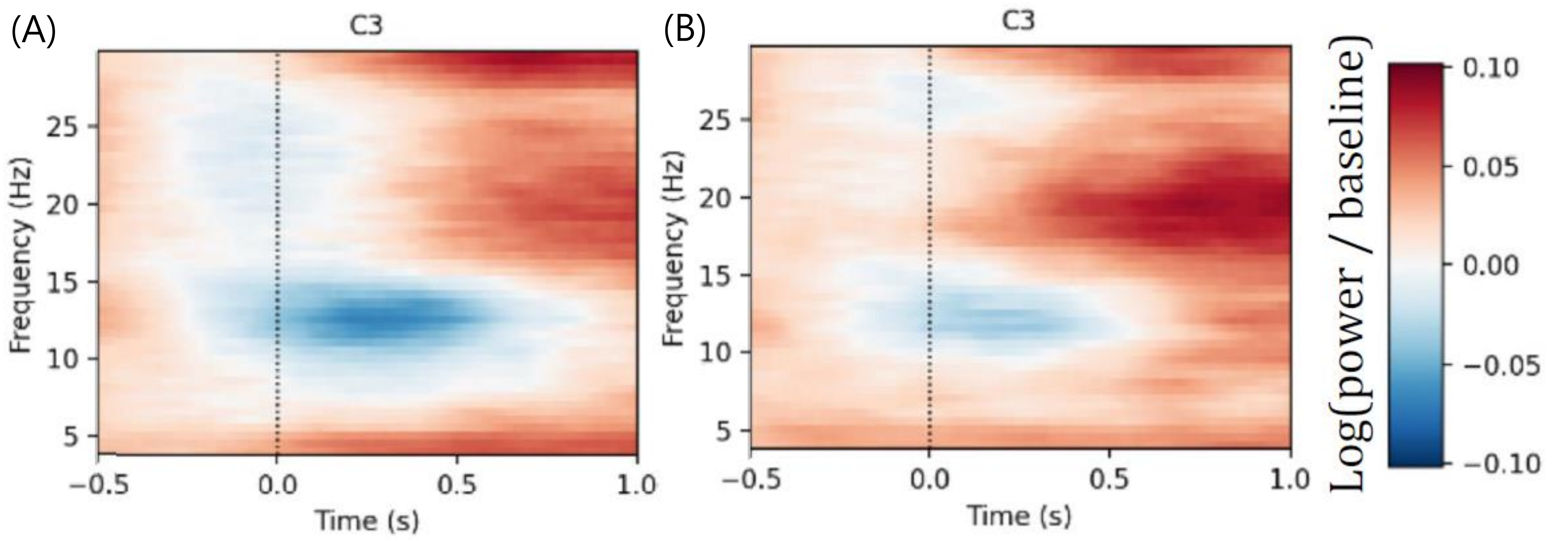

Fig 2. Task-related EEG changes over C3 (A) MVF+PES (B) Non-MVF+PES

Conclusion

The combination of AR-based MVF and PES induced greater and longer sensorimotor cortical activation than PES alone, as reflected by enhanced mu-band desynchronization over C3. These results suggest the synergistic potential of combining immersive visual feedback with somatosensory stimulation as a promising therapeutic strategy for upper limb motor rehabilitation.