

Utilizing a fNIRS-guided brain-computer interface to facilitate observational imitation in poststroke rehabilitation: A randomized controlled trial

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Introduction

Motor imagery (MI), observational imitation, and mirror therapy are established approaches in post-stroke rehabilitation, yet the extent to which patients successfully engage corticomotor networks during MI remains difficult to assess in clinical practice. Functional near-infrared spectroscopy (fNIRS)-based brain-computer interfaces (BCIs) offer the possibility of monitoring cortical activation in real time and delivering feedback contingent upon successful MI. First randomized controlled trials (RCTs) employing fNIRS BCIs have shown promising results in targeting upper limb motor symptoms in stroke survivors [1]. This proof-of-principal RCT study investigated whether a closed-loop fNIRS-guided BCI in augmenting motor imagery (MI) during observational imitation could enhance upper-extremity recovery and modulate neurophysiological markers of motor system plasticity after stroke.

Methods

In this randomized controlled trial, 44 individuals with chronic stroke were allocated to either a real fNIRS-BCI group or a sham-BCI control group. Participants in both groups performed kinesthetic motor imagery followed by observation and imitation of upper-limb movements over ten intervention sessions. In the real BCI condition, instructional videos were triggered only when MI-related activation in corticomotor regions exceeded an individualized fNIRS threshold. In the sham condition, feedback was delivered at fixed intervals independent of brain activity. Clinical outcomes included the Fugl-Meyer Assessment of the Upper Extremity (FMA-UE) and Action Research Arm Test (ARAT). Neurophysiological outcomes included mirror visual feedback (MVF)-induced sensorimotor event-related desynchronization (ERD) measured with EEG and MI-related oxygenated hemoglobin (HbO) responses measured with fNIRS. The protocol has been prospectively registered (NCT06503484).

Results

Forty-four participants completed the protocol. Both groups demonstrated significant improvements in upper-extremity motor function following the intervention. However, no significant between-group differences were observed for FMA-UE or ARAT outcomes. In contrast, the fNIRS-BCI group exhibited significantly greater increases in MVF-induced beta-band sensorimotor ERD bilaterally, indicating enhanced responsiveness to movement-related visual feedback. Within the BCI group, MI-induced HbO responses over the ipsilesional sensorimotor cortex and supplementary motor area

increased significantly across training sessions and was significantly enhanced post-intervention., suggesting improved capacity for voluntary upregulation of corticomotor activity.

Conclusions

Closed-loop fNIRS-guided BCI training did not produce superior clinical motor recovery compared with an active sham intervention but induced measurable neurophysiological changes associated with enhanced corticomotor self-regulation and responsiveness to visual feedback. These findings support the feasibility of fNIRS-based neurofeedback as a tool for modulating post-stroke brain activity and suggest that future research should focus on translating these neurophysiological effects into clinically meaningful functional gains.

References

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