Facilitating Effects of Transcranial Direct Current Stimulation on EEG-Based Motor Imagery BCI for Stroke Rehabilitation

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Abstract. This clinical trial investigates the facilitating effects of combining tDCS with EEG-based motor imagery Brain-Computer Interface (MI-BCI) robotic feedback compared to sham-tDCS for upper limb stroke rehabilitation. 32 hemiparetic stroke patients were recruited and screened for their ability to use EEG-based MI-BCI. Subsequently, 17 of these patients who passed screening and gave further consent were randomized to receive 20 minutes of tDCS or sham-tDCS prior to 10 sessions of 1-hour MI-BCI with robotic feedback for 2 weeks. The offline and online accuracies of detecting motor imagery from idle condition for the calibration session and the evaluation part of the 10 rehabiltiation sessions were respectively assessed. The results showed that there were no significant difference in the accuracies of the calibration session from both groups, but the online accuracies of the evaluation part of 10 rehabilitation sessions of the tDCS group were significantly higher than the sham-tDCS group. Hence the results suggest towards tDCS effect in modulating motor imagery in stroke.

Keywords: Motor Imagery, transcrianal direct current stimulation, stroke rehabilitation.

1. Introduction

Transcranial Direct Current Stimulation (tDCS) is a noninvasive, safe, and relatively painless brain stimulation technique for modulating cortical activity, and is also used to facilitate treatments of various neurologic disorders [Schlaug et al., 2008]. A study had shown that reducing excitability in the contra-lesional hemisphere by cathodal tDCS and enhancing excitability in the ipsi-lesional hemisphere by anodal tDCS improved motor performance in stroke [Fregni et al., 2005]. Another study had showed evidence that majority of stroke patients could operate EEG-based MI-BCI [Ang et al., 2011], and preliminary results had shown that EEG-based MI-BCI with robotic feedback rehabilitation is effective in restoring upper extremities motor function in stroke [Ang et al., 2010]. Hence the objective of this clinical trial is to investigate the facilitating effects of combining tDCS with EEG-based motor imagery Brain-Computer Interface (MI-BCI) robotic feedback compared to sham-tDCS for upper limb stroke rehabilitation.

2. Material and Methods

27 channels of EEG data were collected using Nuamps acquisition hardware sampled at 250 Hz from 32 sub acute and chronic patients recruited from a local hospital. Since not all stroke patients could operate EEG-based MI-BCI [Ang et al., 2011], the patients recruited first underwent a MI-BCI screening session. A total of 160 trials of EEG that randomly comprised 80 motor imagery of the stroke-affected upper limb and 80 idle condition were collected. The 160 trials of data were then analyzed offline using the FBCSP algorithm [Ang et al., 2012] without any removal of artifacts such as electrooculogram. 23 out of the 32 recruited patients passed the screening sessions and 17 gave consent for further study. Each subject enrolled for the further study was then randomized into either the tDCS ($n = 8$) or the sham-tDCS ($n = 9$) group. Subjects in both groups first underwent a calibration session whereby the stroke affected-limb of the subject was strapped to the MIT-Manus robot. 160 trials of EEG data that comprised 80 MI of stroke-affected upper limb and 80 idle condition were then collected similar to the screening session. Subsequently, the subjects in both groups underwent 10 rehabilitation sessions for 2 weeks, 5 times a week. Each rehabilitation session comprised of 20 minutes of tDCS or sham-tDCS, followed by 8 minutes of evaluation and 1 hour of therapy using EEG-based MI-BCI that comprised 160 MI of the stroke-affected upper limb with online robotic feedback. For subjects in the tDCS group, direct current was applied using a saline-soaked pair of surface

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sponge electrode from a battery-operated constant current stimulator with at an intensity of 1 mA with the anode placed over the M1 motor cortex of the ipsi-lesional hemisphere and the cathode placed over the contra-lesional M1. For subjects in the sham-tDCS group, the current was only applied for 30 s to give the sensation of the stimulation. During the evaluation part of each rehabilitation session, the online accuracy of detecting motor imagery was first evaluated by collecting 40 trials that comprised 20 MI of the stroke-affected upper limb and 20 idle condition. Online robotic feedback was provided during the evaluation part when MI was instructed and detected.

The accuracies of classifying motor imagery of the stroke-affected limb versus the idle condition of the tDCS group were then compared with the sham-tDCS group by performing session-to-session transfer using the FBCSP algorithm trained on first 80 trials to the subsequent 80 trials of the data collected from the calibration session. Subsequently, the accuracies were also compared by performing session-to-session transfer using the FBCSP algorithm trained on the calibration session to the evaluation part of the 10 rehabilitation sessions.

3. Results

The results on the screening session-to-calibration session transfer show that the average accuracy of classifying the motor imagery of the stroke-affected limb versus the idle condition from the tDCS group (74.22%) is higher than the sham-tDCS group (66.67%), but no significant difference is found ($p = 0.29$).

Fig. 1 shows the averaged online accuracies of detecting motor imagery versus the idle condition across the evaluation part of the 10 rehabilitation sessions. The results showed deviation of online accuracies across subjects and sessions, and the averaged accuracies of the subjects from the tDCS group across most of the 10 rehabilitation sessions are higher than the sham-tDCS group. The average accuracy of classifying the motor imagery of the stroke-affected limb versus the idle condition from the tDCS group (62.22%) is significantly higher than the sham-tDCS group (57.04%, $p = 0.0096$).

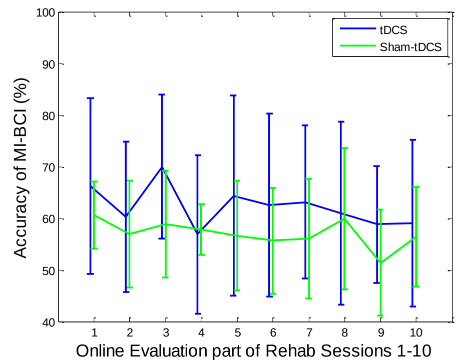

Figure 1. *Plot of the average accuracies of detecting motor imagery (MI) of the stroke-affected hand versus the idle condition for the tDCS and the sham-tDCS group during online evaluation part of the rehabilitation sessions using the FBCSP algorithm trained on data from the calibration session. The accuracies are computed online by performing session-to-session transfer using the FBCSP algorithm trained on data from the calibration session to the evaluation part of each of the 10 rehabilitation sessions. The horizontal axis represents the 10 rehabilitation sessions that the patients underwent.*

4. Discussion and Conclusion

The results showed no significant difference in the accuracies of the calibration session from both groups, but the online accuracies of the evaluation part of the 10 rehabilitation sessions of the tDCS group are significantly higher than the sham-tDCS group. This suggest towards tDCS effect in modulating motor imagery in stroke.

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