High density transcranial direct current stimulation modulates broadband cortical activity: a simultaneous tDCS-EEG study

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TRANSCRANIAL direct current stimulation (tDCS) is a promising method for noninvasively modulating neural activity in the human brain. tDCS induces polarity specific effects on cortical excitability: anodal stimulation increases spontaneous cortical activity through tonic depolarization of resting neuronal potentials while cathodal stimulation decreases spontaneous cortical activity through tonic hyperpolarization [1]. In addition, tDCS can induce long lasting after effects on cortical excitability and network connectivity [2]. tDCS is considered to have great potential for use in clinical rehabilitation of neural disorders [3]. However, there is a significant lack of functional neuroimaging data with regards to the real-time effects of tDCS. Collection of electrophysiological data using electroencephalography (EEG) is particularly challenging during tDCS due to artifacts related to the stimulation. The purpose of this study was to develop data analysis methods for EEG collected during high density tDCS of various cortical regions of interest. Furthermore, we utilized time-frequency analysis to delineate the real-time effects of high density tDCS on spontaneous cortical synchronization.

We recorded eyes-open, resting state EEG using a 64 channel high resolution system before, during and after high density tDCS of the left sensorimotor cortex in eight healthy human subjects. A 4x1 ring electrode configuration was used to administer anodal, cathodal or sham stimulation for each subject in separate experimental sessions. High density tDCS ring electrodes were integrated into the EEG cap in order to simultaneously acquire whole-head electrophysiological data during ongoing stimulation of the ROI. EEG was continuously recorded for a total of 20 minutes in each session, with tDCS being applied during the middle 10 minutes using a 1.0 mA current. Following experimentation, all EEG data were downsampled to 250 Hz, re-referenced and filtered using a bandpass filter (2-50 Hz). Epochs containing artifacts and noisy channels were removed following subsequent visual inspection of the data. Finally, independent component analysis was used to identify and remove remaining EEG artifacts due to eye blinks, muscle activity and tDCS.

Using our methods we were able to successfully remove EEG artifacts related to tDCS and delineate its effects on spontaneous cortical rhythms in real-time. For the anodal configuration EEG recordings revealed broadband, local increases in cortical activity over the left sensorimotor cortex during stimulation, particularly in the theta, alpha and beta bands. In contrast, the cathodal configuration resulted in broadband decreases in cortical activity in bilateral frontal cortex during stimulation. Large variations in subject responses to simulation were observed, and a subgroup of individuals also showed increased spontaneous synchrony in occipital and right posterior parietal cortex during stimulation using the anodal configuration. These findings provide evidence for the polarity specific effects of tDCS on neural activity and suggest that tDCS can modulate both local and global cortical excitability through distributed network effects. Further development of our tDCS-EEG methods could lead to additional insights into the physiological mechanisms of action of tDCS and allow for improved subject-specific targeting of stimulation. Importantly, such methods could significantly improve the capacity to obtain rehabilitation-related biomarkers using EEG for evaluation of tDCS-based clinical protocols.

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