Evaluation of Motor Network Interactions using Combined Transcranial Magnetic Stimulation and EEG

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SIMULTANEOUS transcranial magnetic stimulation (TMS) and scalp electroencephalography (EEG) can be used to assess cortical reactivity and connectivity by directly perturbing a cortical region and evaluating the spatial and temporal spread of the evoked activity. The aim of the present investigation is to use simultaneous TMS-EEG to study interactions among motor network areas in healthy subjects.

The motor system includes a network of several areas responsible for various stages of movement planning and execution. TMS is a noninvasive technique that uses brief pulses of electricity through a coil of wire placed next to the scalp to create pulses of magnetic energy that induce focal electric fields inside the brain [1-3]. Combined TMS and EEG allows for a measure of event-related activity in which the spatial and temporal aspects of the source are known, providing a notion of causality. Simultaneous TMS and EEG can therefore be used to investigate the dynamic mechanisms used by brain areas to compensate for brief disruptions in brain activity. MRI connectivity studies and early TMS/EEG studies involving stimulation of motor cortex demonstrated a propagation pattern involving ipsilateral primary motor cortex, premotor cortex, and supplementary motor area, followed by contralateral motor areas [4–6]. However, motor network interactions need to be further characterized using TMS/EEG to evaluate whether combined TMS/EEG offers connectivity information that could be used as a biomarker of pathological interactions in patient populations. The aim of this research is to evaluate the event related activity and causal interactions among motor areas in healthy subjects using a combined TMS/EEG approach.

Six healthy subjects were recruited for participation. The study was approved by the Institutional Review Board of the University of Minnesota. 64 channel EEG data were continuously acquired using TMS-compatible amplifiers (Brain Products). Single TMS pulses were applied at motor threshold to hand motor areas using a 70-mm figure of eight coil connected to a Magstim Rapid^2 stimulator. The neuronavigation system incorporated both anatomical and functional MRI data for each subject to ensure precise positioning of the TMS coil over the selected cortical regions. The EMG response was continuously monitored bilaterally from the first dorsal interosseous. Principle Component Analysis (PCA) was used to separate TMS-induced artifacts from physiological signals based on the spatial distribution and time course of the artifactual components. TMS artifacts were further reduced by removing the epoch from 0 to 20 ms relative to the TMS pulse and performing interpolation. The resultant data were bandpass filtered and analyzed to extract spatial, temporal, and spectral properties of the event related activity.

The frequency content of the EEG response and spatiotemporal propagation of TMS evoked activity were similar for hand motor areas of both hemispheres, and across subjects. TMS evoked primarily beta-band oscillatory activity in bilateral motor areas. The time course of TMS evoked topographies revealed initial activation at the stimulation site, with propagation to pre-motor and contralateral motor areas. This suggests that combined TMS and EEG can provide causal connectivity information regarding motor network interactions, especially with regard to interhemispheric connections. Therefore, the combined TMS/EEG approach is suitable for use in future investigations aiming to identify and characterize pathological motor network interactions in stroke patient populations.

References

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