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Visualizing Beta Band ERD In Stereoscopic 3D: Exploring Brain Activity During Fatiguing Contractions

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Introduction: Electroencephalography (EEG) signals, a direct measure of neuronal activity, have high temporal resolution but poor spatial resolution which renders them ineffectual for analysis of complex spatial-temporal tasks such as isometric muscle contractions. At resting state, the neuronal activity in the brain is synchronous and cortical signals show low-frequency oscillations with high signal amplitude or power. During a motor event, the brain traverses into an activated state and the neuronal activity is not synchronous anymore leading to Event-Related Desynchronization (ERD)[1]. ERD is a reduction in power of cortical signals from a resting state baseline and is thought to indicate cortical processing. While spectrograms adequately explain this change in power of the neuronal signal in a frequency band over time, they fail to elucidate interactions between regions of the brain, which are necessary in understanding complex neural phenomenon, such as a motor event. A novel immersive visualization technique to analyze EEG data, measured before and after fatigue-inducing tasks, is described as an attempt to provide an alternate platform for signal analysis that incorporates spatial information.

Materials and Methods: EEG data sets were collected at 1000Hz with 64 scalp electrodes from a neurologically intact subject performing isometric elbow flexion and extension fatiguing task with the dominant arm. Data sets recorded before and after the fatiguing task contained 40 trials each of 5-second baseline data followed by 5 seconds of contraction. Preprocessing of EEG data was performed with EEGLAB and AMICA ICA Algorithm (Swartz Center for Computational Neuroscience-UCSD, La Jolla, CA) in MATLAB® R2016a. Data analysis was performed using Brainstorm (http://neuroimage.usc.edu/brainstorm) to obtain source localization of EEG signals. Marquette University Visualization Lab's (MARVL) immersive environment, consisting of four display surfaces with immersive viewing and motion tracking equipment, was used to render this data for visual analysis in stereoscopic 3D. Unity® software was used to incorporate the 3D elements such as the electrodes and the brain along with interactable components that assisted with navigation. The process flow for Unity was created to support dynamic changes in the data sets to allow inclusion of additional data for analysis.

Results and Discussion: Immersive visualization of EEG data allowed for the collective observation of differences in spectrogram data elements, which made the identification of important differences visually clearer than in 2D data formats. ERD was observed in the beta band (12-20Hz) as a drop in signal power with respect to the baseline. Collective quantitative changes between baseline and ERD data sets were visualized, thus percentage changes from a resting state to activated state for every electrode after a fatiguing exercise could be observed all at once. This method allowed observation of changes in beta band or alpha band (8-12Hz) or both frequency ranges along with the spatial information of each electrode.

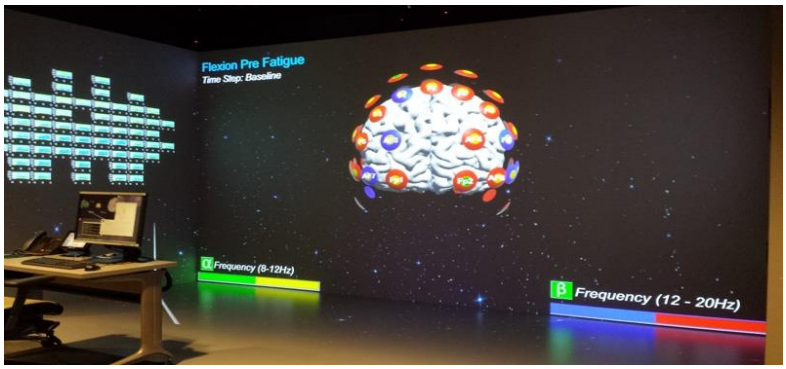

Figure 1: Colored discs or electrodes on the surface of the model of the brain show ERD as the change from resting state to activated state during fatigue. The electrodes show baseline and ERD in alpha and beta frequency ranges. Color gradient for each frequency range shows the intensity of percentage change from baseline for each electrode. The left wall shows the spectrogram for all 64 electrodes, collectively or individually, where time is represented on the x-axis and frequency on y-axis.

Conclusions: A non-invasive quantification of neuromuscular events, incorporating spatial information, will allow for better analysis of bioelectric signals. This novel immersive visualization technique provides an alternate rendering of preprocessed EEG data, which allows for the total observation of EEG signal differences present during an ongoing task.

References: 1. Wörtz M, Pfurtscheller G. ERD/ERS patterns reflecting sensorimotor activation and deactivation. *Prog Brain Res*. 2006;159:211-222. doi:10.1016/S0079-6123(06)59014-4.