Chapter 92

Mental Fatigue Assessment in Prolonged BCI Use Through EEG and fNIRS

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Amyotrophic lateral sclerosis (ALS) is a neurodegenerative disease that causes loss of motor neurons and progressive weakness including loss of speech.[1] As a result, affected individuals become "locked in" and unable to communicate. The use of brain–computer interface (BCI) can enable communication and increase quality of life, but to date the effects of mental fatigue have been ignored. Mental fatigue due to prolonged BCI use can reduce the accuracy and increase the response time decreasing the utility of the BCI and reducing user satisfaction.

In this project, our aim is to identify neuroimaging-based biomarkers of mental fatigue associated with extended BCI use. Awareness about the factors underlying BCI performance and use could allow for development of flexible systems that are adaptable to different clinical profiles.[2] We have utilized both electroencephalography (EEG; for electrophysiological activity) and functional Near-Infrared Spectroscopy (fNIRS: cortical hemodynamic activity) to detect mental fatigue during use of P300-based BCI paradigm. The central hypothesis of this project is that mental fatigue during prolonged BCI use induces changes in brain activation as measured by fNIRS and EEG.

Eight participants took part in this study (6M, 2F), two ALS patients (2M) (Age = Mean + SD; 58.5 ± 16.3 years) and six healthy controls (Mean Age = 25.3 ± 2.7 years). Prior to the study, all participants consented and written informed consent was obtained based on the approved protocol by the Institutional Review Board of Drexel University. All subjects were asked to use P300-based BCI to complete a spelling task. For the first half of the BCI protocol, the subject's copy spelled three words. The three words they spelled for accuracy after calibration were DREXEL, UNIVERSITY, and BRAIN. In the second half of the BCI protocol, the subjects spelled three more words. The words were COMPUTER, INTERFACE, and 8675309. Sixteen channel EEG and prefrontal fNIRS were collected simultaneously. Before BCI calibration and between the BCI2000 protocol blocks, subjects completed a continuous performance task (CPT) that was designed to assess participants' vigilance, and behavioral performance.[3] CPT task was completed four times (repetitions) throughout the entire protocol. The task lasts for approximately 5 min followed by 5 min to complete the modified Chalder fatigue questionnaire to subjectively assess their mental fatigue level as a comparison to EEG and fNIR signals.[4] Linear Mixed Models with Repeated Measures were used for statistical comparison.

Preliminary results of fNIRS data during execution of the CPT (mean oxygenated-hemoglobin changes in left dorsolateral prefrontal cortex, optode 4) indicated a decline over sessions ($F_{2,3.4} = 23.15$, $P = .01$) but no group differences ($F_{1,15.5} = 1.25$, $P > .05$); see Fig. 92.1. Preliminary results of EEG data during the BCI sessions [average Parietal zero scalp electrode (Pz) P300 amplitude] indicated a significant difference between the two sessions ($F_{1,11.9} = 4.85$, $P < .05$) and significant difference for group ($F_{1,11.9} = 18.20$, $P < .01$). These preliminary results indicate that fNIRS and EEG can be used to assess brain activation changes during prolonged BCI use. Further analysis will be performed to identify biomarkers of mental fatigue. Future studies are needed to validate and eventually incorporate these into online use to improve BCI classifier performance and BCI usability.

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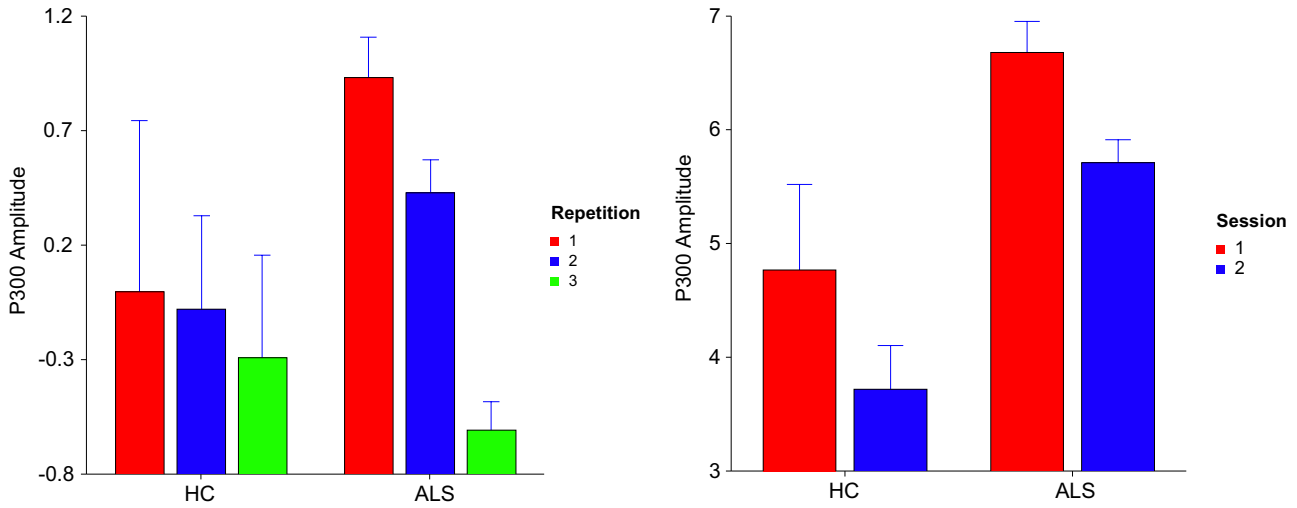

FIGURE 92.1 Average oxyhemoglobin changes during CPT task comparison across three repetitions (left). Average Pz P300 amplitude during the two BCI sessions (right).

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