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Physiologic Manifestations of Communication & Learning in a Patient with Remote TBI & Disorders of Consciousness: Lessons from Establishing a Non-Invasive BCI Protocol

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Introduction: Patients with disorders of consciousness (DoC) can present with cognitive motor dissociation (CMD), in which they can follow cognitive commands without motor expression, limiting their interaction with their environment using traditional communication methods. The mindBEAGLE, a noninvasive brain computer interface (BCI), has shown promise in analyzing neuroelectrical activity such as event-related potentials (ERP) on electroencephalography (EEG) to assess communication and command following in DoC patients. Here we present results of a DoC patient using the mindBEAGLE in terms of physiological manifestations and command following. Our subject is a 28-year-old male who sustained a traumatic brain injury (TBI) in 2018 from a fall resulting in a multicompartmental hemorrhage.

Materials, Methods: Subject recruitment was based on the JFK coma recovery scale - revised (CRS-R) designating unresponsive wakefulness state (UWS) or minimally conscious state (MCS) patients. Our subject's CRS-R score upon evaluation was 7 out of 23, consistent with UWS. MindBEAGLE paradigms of auditory evoked potentials (AEP) and vibrotactile evoked potentials (VEP) using the P300 ERP approach, and motor imagery (MI) using the event related desynchronization/synchronization (ERD/ERS) approach were used as measures of functional brain activity. CRS-R scores and physiologic parameters such as blood pressure were collected before and after each session by a physician. Heart rate and blood oxygen saturation was collected intermittently over the course of multiple paradigms administered during each session. Relationships were analyzed using Pearson correlations between physiologic parameters and classification accuracies, and significance was evaluated using the student's t-test.

Results: The patient demonstrated an initial improvement in classification and yes/no question accuracy during the initial 3 evaluation sessions, but had a sharp decline in the 4th evaluation session; accuracy slowly improved into the 5th evaluation session and 2 subsequent treatment sessions (total 7 sessions). This accuracy pattern was positively correlated with changes in the patient's mean arterial pressure (MAP) ($r=0.48$, $p=0.00015$), and negatively correlated with changes in heart rate ($r=0.61$, $p=0.00062$). Quantitatively, after the first session, the CRS score increased from 7 to 10, and all subsequent CRS scores ranged from 8-10 pre-session and 9-10 post session. Qualitatively, the patient was initially only able to fixate and track his mirror image, but began to track the examiner's finger after the 3rd session. There were no significant associations regarding blood oxygen saturation.

Conclusion:
The mindBEAGLE was able to detect a DoC subject's attempts at communication and track paradigm learning over multiple sessions. Physiologic responses were suggestive of increased metabolic demand, conditioning, and potential conscious effort in cognitive tasks. Sessions were overall well tolerated and can be medically feasible in the chronic DoC population.

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