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Tracking variability in subject state and iBCI performance over time

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Introduction: Intracortical brain-computer interfaces (iBCIs) allow individuals with motor impairments to directly control effectors like computer cursors by decoding patterns of neural activity that can be used to control effector kinematics. Fundamental to the iBCI is the mapping between neural activity and intended kinematics. However, non-stationarities in the neural data alter this mapping over time and therefore reduce iBCI performance [1]. It is thought that changes in subject state, such as fatigue or pain, contribute to these non-stationarities. Therefore, accounting for these state changes could allow for more robust implementation, for instance by updating a decoder [2] based on a reference dataset collected when the subject previously had been in a similar state. Here we report an interim analysis of the relationship between subject state (e.g. pain or fatigue) and iBCI performance.

Material, Methods, and Results: As part of an ongoing study, we recorded intracortical activity from the motor cortex of two participants with tetraplegia using intracortical microelectrode arrays (Blackrock Microsystems, Inc., Salt Lake City, UT). Participants completed BCI-controlled cursor tasks in lab and home environments. During each session, the participant completed a structured task, which was a gamified 2D center-out task featuring both translation and click [3]. Subjective ratings of pain, fatigue, and sleep quality on a 0-10 scale were recorded before each session. Seventeen days of data were collected from participant P2 and 5 days from participant P3. Figure 1a shows that both participants experienced pain and fatigue, as well as less than optimal sleep, on all days of testing with more variability for P3. Figure 1b shows that while success rates were generally high, they varied from day to day for both participants. Higher fatigue was inversely correlated with success rate in P3 ($r = -0.94$, $p = 0.018$) while no other state variables were predictive of performance in either subject.

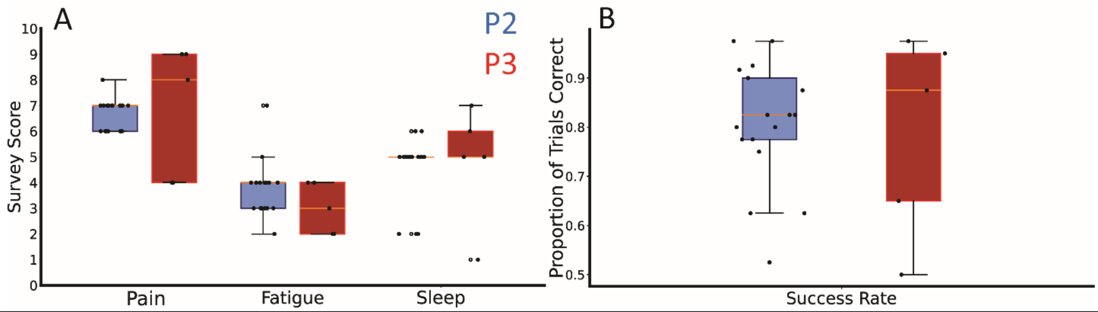

Figure 1 – Distribution of subject state survey scores and iBCI success rate. A. Participants indicated perceived pain level (0=no pain, 10=worst pain imaginable), fatigue (0=no fatigue, 10=most fatigue imaginable), and sleep quality (0=worst sleep imaginable, 10=best sleep imaginable). B. Fraction of trials (typically 40 total) completed correctly in the click-and-drag task [3].

Discussion: The participants experienced variability in both subject state and BCI performance despite both having multiple years of experience; 7.5 years for P2 and 2.5 years for P3. There was a relationship between fatigue in one participant and performance, but these basic survey metrics were not able to explain all the variability seen across days in performance. Pupillometry data is being collected from both participants that may yield greater insight into subject state and task engagement [4].

Significance: We observed day-to-day variability in both subject state and performance metrics across two participants with significant BCI experience. Improvements to iBCI design to make them more robust to this variability could promote wider clinical adoption.

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