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Autonomic Activation, Mental Effort, and Fatigue While Using Non-Implantable RSVP and Matrix cBCIs

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Introduction: Non-implantable communication BCI (cBCI) systems may offer substantial benefits to individuals with communication impairments. However, prior research has suggested that sustained use of these systems may be impeded by factors such as fatigue, sleepiness, and boredom [1]. Relatedly, there is little extant data to directly compare differences in mental effort or autonomic activation between two common P300-based cBCI paradigms: Rapid Serial Visual Presentation (RSVP) and Matrix. The present study compared measurements of autonomic activation during both RSVP and Matrix tasks, as well as self-reported mental effort, fatigue, sleepiness, and boredom. We predicted elevated autonomic and self-report levels during RSVP as compared to Matrix, and also increases in these measures over time.

Material, Methods and Results: Twenty-four healthy adult participants (age range 22-49 years) provided physiologic and self-report data during a single experimental visit to OHSU. Participants completed P300-based RSVP and single-character Matrix spelling tasks in BciPy [2], both of which were delivered in random counterbalanced order across individual sessions. Each paradigm included calibration (50 inquiries with 1 target and 9 non-target letters, with an additional 5 inquiries with 10 non-targets), resulting classifier calculation, and three copy-spelling sessions to complete 5-letter words. EEG was recorded with a dry-sensor DSI VR-300 (Wearable Sensing); autonomic measures were collected with a VitalStream CT5 (Caretaker Medical) and included systolic and diastolic blood pressure, mean arterial pressure, heart rate (HR), and respiration rate. Self-reported state sleepiness [3], mental fatigue [4], and boredom [5] were collected before/after each calibration and copy-spelling phase. Mental effort was measured using a single item from the Multidimensional Fatigue Inventory, "It took a lot of effort to concentrate on things." The entire visit with a total of two calibrations and six copy spelling tasks lasted approximately 105 minutes.

Calibration AUC estimates during RSVP (M=0.85; SD=0.10) were slightly lower on average than Matrix (M=0.88; SD=0.10), though this difference was not significant (p=0.08). The number of target letters correctly copied during copy-spelling was significantly higher in Matrix (M=13.54; SD=3.14) than in RSVP (M=12.08; SD=3.90; p=0.012). Results indicated a main effect of time on all self-report measures, such that all self-reported fatigue and effort measures increased significantly over the course of the visit (all p values < 0.001). The changes in self-report measures from the beginning to the end of RSVP and Matrix were not different. There were significantly greater increases in all self-report levels from the beginning to the end of calibration, as compared to the beginning to the end of copy-spelling (all p values ≤ 0.006).

With regard to the autonomic measures, we observed a main effect of paradigm (RSVP vs. Matrix) for mean HR (p=0.005), which increased during RSVP (M=72.15; SD=9.42) as compared to Matrix (M=70.60; SD=8.51). There was a main effect of task phase as well, such that all autonomic measures were higher during calibration relative to copy-spelling (all p values ≤ 0.035).

Conclusion: Participants demonstrated significant increases in self-reported mental effort, fatigue, sleepiness, and boredom across completion of two cBCI paradigms and following calibration relative to copy-spelling. Autonomic measures increased during calibration relative to copy-spelling, suggesting calibration is more effortful and fatiguing than copy phrase. Elevated HR during RSVP likewise suggests increased effort.

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