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Inter-Stimulus Latency Jitter in RSVP Keyboard: Effects on Attentional Event-Related Potentials

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Introduction: It is well-established that sequential presentation of stimuli can affect measurements of event-related potentials (ERPs) from electroencephalograms (EEGs), particularly when the neurologic processing of subsequent stimuli overlap in time [1]. Prior work suggests that steady-state visual presentation of letter stimuli has the potential to obscure EEG-based measures of attention [2]. Despite this understanding, the vast majority of brain-computer interface (BCI) P300-based systems do not explicitly control for overlapping stimulus presentations. One possible solution to improve ERP measures in the presence of adjacent stimuli is to vary ("jitter") inter-stimulus latencies [1].

Material, Methods and Results: This study investigated interference of steady-state visual-evoked potentials (SSVEPs) with attentional ERPs in a P300-based BCI for communication, RSVP Keyboard. EEGs were recorded from 24 adults without SSPI (age 18-76) during three rounds of RSVP calibration/copy-phrase with letters presented at a rate of 5 Hz using python-based BciPy [3]. Three levels of range of stimulus jitter were applied in an attempt to attenuate overlap and SSVEP effects in ERPs: 1) conventional no inter-stimulus jitter; 2) ±50 ms; and 3) ±100 ms. A final 1 Hz calibration was completed in order to examine non-overlapping ERPs. Results showed significant N200 and P300 ERP attention effects (see Fig. 1; all p values < .001), as well as a significant reduction in noise (as assessed by the standard deviation of target ERPs) in both jitter conditions, relative to the no-jitter condition (both p values < .05). Classifier models from calibration runs were generated in BciPy using PCA pre-processing and a regularized discriminant [3]. However, there were no significant differences in classifier performance (AUCs or balanced accuracy), copy-phrase accuracy, or ERP attention effects between jitter conditions (all p values > .10). Approximately half of participants did not independently notice jitters, and there was no clear user preference for or against stimulus jitter. Supplementary analyses examined measures of attentional alpha attenuation.

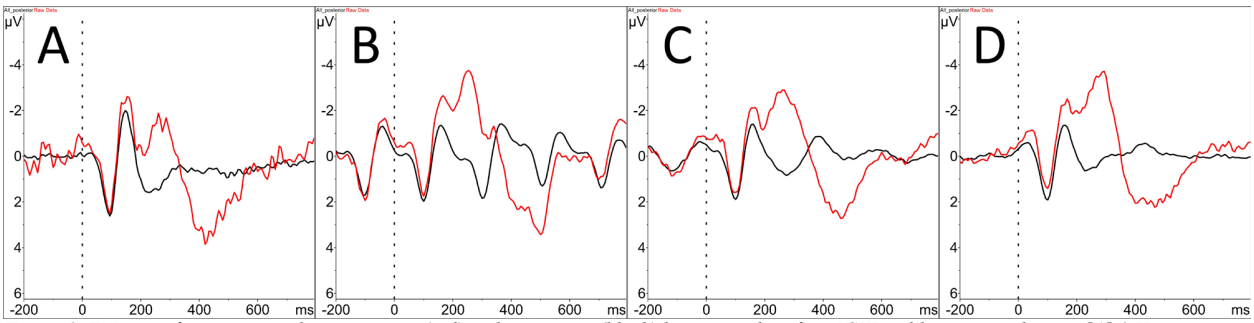

Figure 1. ERP waveforms averaged across target (red) and non-target (black) letter stimuli in four RSVP calibration conditions: [A] 1 Hz presentation with no stimulus jitter; [B] 5 Hz presentation with no jitter; [C] 5 Hz presentation with small jitter of ±50 ms; and [D] 5 Hz presentation with a large jitter of ±100 ms. Intrusion of the SSVEP signal is greatly decreased in conditions [C] and [D], compared to [B].

Discussion: Results suggest that even moderate stimulus "jitter" has the potential to improve measurement of attentional ERPs for BCI control. However, it is unclear how these jittered presentations might impact brain indices of attention in different BCI paradigms. Classifier performance was not obviously affected by the presence of the SSVEP, even with greater signal-to-noise (i.e., P300-to-SSVEP ratio). Overlapping stimulus processing does not seem to necessarily hurt ERP-based target classification, even though it appears to alter other EEG measures of attention (e.g., event-related alpha attenuation).

Significance: Jittered inter-stimulus latencies have the potential to improve BCI performance, especially as a relatively quick and imperceptible modification to extant designs.

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