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Investigating the Impact of Ecologically Valid Interactions on Rapid Serial Visual Presentation-based Brain-Computer Interface Performance

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Introduction: The Rapid Serial Visual Presentation (RSVP) is an experimental approach to BCIs in which a series of images is displayed at a high speed. Participants are asked to differentiate between a set of target images and a set of non-target images, where the P300 ERPs is evoked by the target image, but not by the non-target image [1, 2]. The automatic identification of this response in a robust way allows this paradigm to produce a functional interface relating a user's internal brain state to events in the external environment. While the RSVP approach produces impressive results in lab-based environments, translation of this technology into consumer contexts requires a better understanding of performance in ecologically valid settings, for example the use of the BCI to enhance experiences in online worlds, metaverse and gaming contexts. Such application scenarios are characterised by much less constrained user behaviour some of which is entirely necessary for the normal expected interactions we typically encounter in such applications. Examples include talking, head and hand movement. In this study we examine how such interactions induce performance degradations in an RSVP paradigm in a quantified way, explicitly articulate the signal processing challenges to mitigate this and present open datasets for researchers to benchmark performance.

Material, Methods and Results: The data collection protocol is split into two sections: 1) the standard paradigm, in which the subject performs the target search task while sitting quite still in front of the monitor; and 2) the RSVP paradigm with the induced noise, in which the participant voluntarily generates three distinct noises (i.e., walking, nodding, and talking) while doing the RSVP task. The dataset contains EEG responses to 2100 images (both target and standard images) from a single participant utilizing an Eego Sports device with 32 channels and a 1 kHz sampling rate. The participant completed three sessions consisting of six blocks per session (3 for the traditional RSVP and 3 for the RSVP with the induced noise). In each 90-second block, 360 images were displayed at a rate of 4 Hz, with 36 target images intermixed randomly among 324 non-target images.

The raw signal was passed through a band-pass filter (.5Hz to 30Hz), and then time-series characteristics were recovered from -.2s to 0.8s relative to visual stimulus onset. The common average referencing was carried out prior to the epoch extraction. Figure 1 depicts a P300 response at channel O1 in an RSVP task.

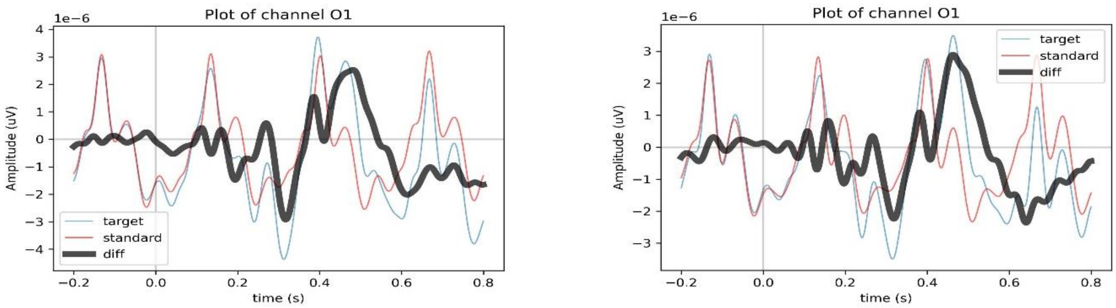

Figure 1. P300-related activity can be seen at channel 01 at around 390ms. The difference (diff) of targets (red) and standards (blue) is shown as average(target) – average(standard) in black color. The left and the right figure illustrate the traditional and the induced noise RSVP, respectively.

Discussion: The aforementioned illustration makes it evident that the P300 peak occurs at around 390ms in both scenarios. The ERP average also shows a characteristic SSVEP response.
When using an RSVP target search paradigm, the P300 isn't the only ERP that often shows up. In addition to P3, earlier ERPs like N2 and P2 are also present, and the three of them together may be quite helpful in producing discriminative knowledge for classification. In the future, we want to integrate advanced denoising algorithms that allow us to achieve the same P300 response in both a standard lab environment and a dataset with inserted noise.

Significance: In order to use a BCI system in a practical situation, it is necessary to gather information in a setting that is distinct from a controlled environment. The goal is to have such algorithms that provide the most accurate predictions possible in real time.

References:

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