How Does the Presence of Non-Target Stimuli Change the Brain Potentials in the P300-Based Brain Switch Paradigm?

Sergei L. Shishkin, *Member, IEEE*, Kristina D. Vigasina, and Yuri O. Nuzhdin

A BRAIN switch is the system for sending a single command at a time moment defined by the user (asynchronously) without frequent false activations. An effective brain switch can be designed using the P300-based brain-computer interface (P300 BCI) paradigm [1] [2], although this BCI is typically used for choosing from multiple commands. With the standard P300 BCI, the user concentrates on stimuli presented in one position (target stimuli) while ignoring the stimuli in other positions (non-target stimuli). The highest EEG response (event-related potentials, ERPs) indicates the target position and the BCI selects the command associated with it. In the switch designed by Rebsamen *et al.* [1] target stimuli were presented in the center of a 3×3 table, and the user's attention was detected by processing the responses to these stimuli. Non-target stimuli were still present in Rebsamen *et al.* design. We assumed that they impose an unnecessary burden on perception, and proposed to remove them from the switch design. In our "single-stimulus" switch, only the target stimulus position was used. It appeared that the target-to-target interval could be made shorter in this case, enabling faster detection of the command (in 4 s) [2].

It is possible, nevertheless, that the presence of the non-targets can be helpful for operating the switch. First, by masking the target stimulus they may prevent automatic orienting of attention to it when the user has no intention to activate the switch. Although false activation rate of the switch without the non-targets was as low as 0.1 min^{-1} or 0.3 min^{-1}, depending on task [2], our study could not model all possible situations where masking might help. Secondly, the non-targets may force the user to better focus his/her attention and thereby enhance the attentional effects on the ERPs. Indeed, early studies of the single-stimulus paradigm demonstrated that removing the non-targets might lead to lower P300 amplitude [3]. Thus, a trade-off design of the brain switch can be considered: the non-targets are present but made less distractive to enable high target presentation rate. In the current study, we compared the ERPs in such trade-off design and in the single-stimulus design.

14 healthy participants took part in the study conducted in accordance with the Declaration of Helsinki. To make the "distracting power" of the non-target stimuli lower than in a typical P300 BCI, we used the following means: (1) only 4 non-target stimuli positions surrounded the target position (instead of 8 in [1]); (2) only 2 to 4 non-targets flashed between two targets; (3) targets and non-targets had different colors; (4) targets were smileys, while only eyes from the same images were used for non-targets. In both conditions "targets and non-targets" (*"T&nT"*) and "single-stimulus", or "targets only" (*"T"*) the target-to-target interval had the same distribution and ranged 500 to 900 ms. Stimuli were presented per condition in 32 blocks, 6 to 9 targets per block, with breaks between the blocks. Participants counted target stimulus flashing. EEG was recorded at 500 Hz with reference at digitally linked earlobes. After artifact rejection, bandpass filtering (1-45 Hz) and averaging epochs started at the target onsets, ERP component amplitude was measured at the largest peak in a given interval and channels: N1 (170..250 ms, PO7 and PO8), P2 (150..225 ms, Cz and Pz), P300 (300..600 ms, Cz and Pz). N1 was higher in the *T* condition (Wilcoxon test results for the two analyzed channels: p=0.03, p=0.01), while P300 was higher in the *T&nT* condition (p=0.01, p=0.03), and P2 did not differ (p=0.77, p=0.68). Median for the magnitude of the difference for N1 and P300 was of the order of 1 μV in all comparisons. The ERPs pattern was strikingly similar between the conditions.

The small difference between ERPs in the two conditions and the opposite effects for N1 and P300 peaks support the claim of our previous study [2] that the non-target stimuli are not critical for the brain switches. Nevertheless, possible use of non-target stimuli for masking the targets should not be ignored when false activations are especially undesirable.

References

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S. L. Shishkin is with the National Research Centre "Kurchatov Institute", Moscow, 123182, Russia (phone: +7 (499) 196-71-00 ext. 64-97; e-mail: sergshishkin@mail.ru).

Y. O. Nuzhdin and C. D. Vigasina are with the National Research Centre "Kurchatov Institute", Moscow, 123182 Russia.

C. D. Vigasina is also with the Faculty of Biology, Lomonosov Moscow State University, Moscow, 119991 Russia.