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Effects of Off-Site Attention on SSSEP Amplitude

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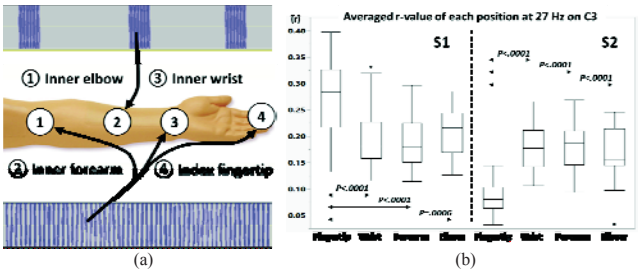
Introduction: Tactile-based BCIs have a potential to help visually-impaired and blind groups. Steady-State Somatosensory Evoked Potentials (SSSEPs) can be elicited on the contralateral areas of the brain with tactile stimuli [1]. Recently, tactile-based BCIs have been hybridized with SSSEP and tactile-P300 to improve BCI classification accuracy, and increase the number of usable classes [2], [3]. This is a preliminary research study to investigate the feasibility of using unattended flutter stimulation (SSSEP) with attended random pulse (tactile P300) via separate tactors on different positions, and how different spatial attention affects SSSEP response.

Material, Methods and Results: We used the same solenoid tactor setup as presented in our previous study [3]. Vibrational stimuli were presented on subjects' fingertip, wrist, forearm, and elbow of dominant side: one tactor presenting random pulses on one of four positions with SSSEP stimulation presented on the other three positions (see Fig 1a). A subset of three of the four locations were chosen as SSSEP stimulation sites to find both the characteristics of nerve pathway and individual differences. This was used to find the most important positions for SSSEP stimulation, which should not be selected for P300 but selected for SSSEP, and vice versa. To generate a random pulse, a 100 Hz sine wave was presented for 250 ms, while SSSEP stimulation was generated by modulating a 27 Hz square wave atop a 100 Hz sine wave. Five healthy subjects conducted 100 pseudo-randomly distributed trials by locations and pulse patterns. Each trial consisted of a 5s rest, 2s reference, and 8s stimulation, during which the subjects were asked to focus only on counting the number of random pulses, which was used as a mental distraction task. EEG signals were recorded with a g.USBamp amplifier using a large Laplacian montage around C3 and C4. BCI2000 was used for data acquisition and stimulus presentation, with EEG signals sampled at 512 Hz and band-pass filtered from 20-56 Hz, then analyzed using Canonical Correlation Analysis (CCA) from 20-29 Hz. The average CCA values showed higher Pearson's correlation (r-value) on the contralateral brain area for 27 Hz, with no differences on the ipsilateral brain area at the same SSSEP frequency. ANOVA of different positions at 27 Hz on C3 for each subject showed S1 had a significantly higher r-value on the fingertip than other positions ($p < .0001$), while S2 showed a significantly lower r-value on the fingertip than other positions ($p < .0001$) (see Fig 1b). S3 ($p = .0619$) and S4 ($p = .0763$) showed marginal significance, and r-value of fingertip was lower than that of the elbow for S3, while there were no significant differences for S4 in post-hoc Tukey tests. S5 showed no significant differences between positions.



(a) (b)

Fig 1. (a) Diagram for tactor positions and stimuli for random pulse
(b) Averaged r-value of each position at 27 Hz on C3 for S1 and S2

Discussion: The results showed unattended flutter sensation could elicit SSSEP on the contralateral brain area by only attending to random pulses presented on the same nerve pathway. Moreover, there were individually different effects of spatial-selective attention on the nerve pathway. Based on these results, this paradigm will be extended to a multi-class tactile hybrid BCI, which will have multiple tactors for P300 and SSSEP for each class. By doing so, we will validate if the result would be the same when extended to multiple classes with multiple tactors for P300 and SSSEP on both forearms.

Significance: We have validated that SSSEP can be evoked through off-site attention. This is important because if P300 and SSSEP are presented on separate tactors at different positions, while asking the subjects to attend only on random pulses, this may reduce the mental workload needed to focus on both flutter and random stimulation for a tactile hybrid BCI system. In addition, these results can potentially improve the performance of a tactile-based BCI system by utilizing user-specific stimulation sites for improved SSSEP response. These features will be used for future research to develop a hybrid BCI for behaviorally non-responsive patients.

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References

[1] A. Z. Snyder, "Steady-state vibration evoked potentials: description of technique and characterization of responses," *Electroencephalogr. Clin. Neurophysiol. Potentials Sect.*, vol. 84, no. 3, pp. 257–268, May 1992.

[2] M. Severens, J. Farquhar, J. Duysens, and P. Desain, "A multi-signature brain-computer interface: use of transient and steady-state responses.," *J. Neural Eng.*, vol. 10, no. 2, p. 026005, Apr. 2013.

[3] I. Choi, K. Bond, D. Krusienski, and C. S. Nam, "Comparison of Stimulation Patterns to Elicit Steady-State Somatosensory Evoked Potentials (SSSEPs): Implications for Hybrid and SSSEP-Based BCIs," in *IEEE International Conference on Systems, Man, and*