Analysis of the brain activated distributions in response to full-body spatial vibrotactile stimuli using a tactile P300-based BCI paradigm

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Abstract— **We report a comparison study of somatosensory evoked potentials (SEP) and classification accuracies in three electrodes (Pz, P3 and P4) on the primary somatosensory cortex (S1), which are associated with the somatotopic arrangements, applying vibrotactile stimuli to user's arms and legs as a tactile P300-based BCI paradigm.**

I. Introduction and Methods

The full-body tactile P300-based brain-computer interface (fbBCI) paradigm is a six-command BCI application which gives spacial vibrotactile stimulus patterns to user's whole body parts [1]. Large transducers are applied to arms (stimulus pattern #1 & #2), shoulder (#3), waist (#4), and legs (#5 & #6) in order to evoke and analyze somatosensory evoked potentials (SEP). The objective of the current study is to reveal a correlation between brain activity distributions on the primary somatosensory cortex (S1) and vibrotactile stimulus patterns for arms and legs. Penfield & Rasmussen reported the somatotopic arrangement that the senses of body functions are distributed on the surface of S1 [2]. Our hypothesis is that a tactile P300-based paradigm can utilize the theory for SEP classifications by attaching electrodes to Pz, P3 and P4 where S1 is located. In the fbBCI paradigm, Pz corresponds to stimulus pattern #5 and #6 (both legs), whereas P3 and P4 to pattern #1 and #2 (both arms) based on the somatotopic theory [2]. In the presented study stimulus pattern classification accuracies and SEP brainwaves in Pz, P3 and P4 are compared in terms of fbBCI stimulus patterns, in other words, stimulated body areas. Ten healthy BCI-users (mean: 21.9) participated in the fbBCI EEG experiment. A g.USBamp (g.tec, Austria) was employed to capture SEP brainwaves, in which the sampling frequency was set at 512 Hz. The experimental sessions were executed five times for each user. The captured SEP brainwaves were conducted ten times off-line classification using the simple moving average (SMA) and non-linear SVM with Gaussian kernel.

II. Results, Discussion and Conclusion

The mean SEP brainwaves of participated ten users in Pz, P3 and P4 were depicted in Figure 1. We assumed that mean SEP of P3 and P4 where mid-parietal on S1 were stronger than SEP of Pz where peripheral on S1 when stimulus pattern #1 and #2 were given to users, according to the somatotopic theory, and we assumed the opposite (Pz > P3 and P4 in pattern #5 and #6) as well. However, the significant differences between those SEPs were not confirmed especially in nearby P300 peaks as shown in gray-shaded area of Figure 1. The somatotopic theory was not reflected on SEP brainwaves in fbBCI paradigm.

The classification accuracy results in Pz, P3 and P4 calculated by non-linear SVM were summarized in Table 1. The Pz scored higher mean accuracy (56.63%; averaged over blue-shaded cells) than the mean of P3 and P4 result (55.77%) in pattern #5 and #6, whereas mean of P3 and P4 scored higher mean accuracy (66.68%; orange-shaded cells) than mean Pz result (66.43%) in pattern #1 and #2. Those differences were slightly, though, it revealed the classification accuracy results were associated with the somatotopic arrangement, as the pattern for each body part scored higher accuracy result.

The presented results implied a possibility applying the somatotopic arrangements to SEP classifications in a BCI study. In the future study another electrodes on S1 (P1, P2 and P5, ... , P10) will be investigated for further development.

TABLE I. Classification accuracy results of each stimulus pattern in electrode channel Pz, P3 and P4.

Stimulus pattern	Electrode channels		
	Pz	*P3*	*P4*
#1 (Left arm)	67.96 %	64.08 %	63.27 %
#2 (Right arm)	64.90 %	73.67 %	65.71 %
#5 (Left leg)	59.39 %	63.47 %	54.29 %
#6 (Right leg)	53.88 %	56.33 %	48.98 %

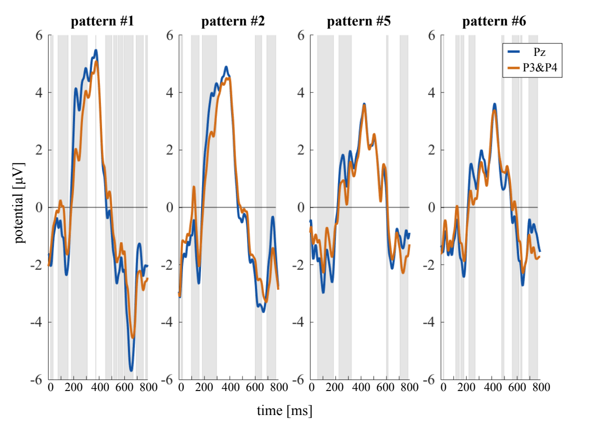

Figure 1. The mean SEP brainwaves of ten fbBCI users with electrodes Pz, P3 and P4. The blue line signified the SEP of Pz, whereas orange depicted mean SEP of P3 and P4. The gray-shaded area denoted the significant difference ($p < 0.01$; Student t-test) between two SEPs at each moment.

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References

[1] Kodama T, Makino S, Rutkowski TM. “Tactile Brain-Computer Interface Using Classification of P300 Responses Evoked by Full Body Spatial Vibrotactile Stimuli”. In: APSIPA ASC 2016. Jeju, Korea: IEEE Press; 2016. p. paper ID: 176.

[2] Penfield W, Rasmussen T. “The cerebral cortex of man”. MacMilan Company, 1952.