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Design of Duty-cycle Screening Paradigm for Steady-State Somatosensory Evoked Potential

Young-Jin Kee, Dong-Ok Won, and Seong-Whan Lee*

Department of Brain and Cognitive Engineering, Korea University, Seoul, Korea

*Seoul, 02841, Republic of Korea. E-mail: sw.lee@korea.ac.kr

Introduction: Steady-state somatosensory evoked potential (SSSEP) has been developed by several brain-computer interface (BCI) research [1-2]. However, the recent SSSEP-based systems showed the low performance for controlling the external devices efficiently. Hence, we suggest a screening technique that can reflect subject-dependent frequency and duty-cycle. In this study, we compared the proposed screening method with normal screening method (frequency only) for demonstrating the necessity of the proposed screening method.

Material, Methods and Results: Electroencephalogram signal was recorded using 17 channels following the international 10-20 system. In the screening session, tactile stimuli was attached on the index finger at a time (left or right). First, the fixation cross (+) appeared during 5 seconds for obtaining the SSSEP in the resting state which means that tactile stimuli were still activated but there was no attention to the stimuli. Then, subjects were instructed to concentrate to attention cue during 3 seconds. During screening session, tactile stimuli consist of nine frequencies (15-33 Hz in 2 Hz steps) and each frequency has nine duty-cycles (10-90% in 10% steps) with 5 times iteration. Total 450 trials were conducted on each hand in this experiment. Increase of spectral power (from attention to rest) was calculated by Fast Fourier Transform (FFT) analysis for finding optimal stimuli. We selected optimal stimuli when the SSSEP had the highest increase of spectral power in the obtained frequency and duty-cycle. In the test session following screening session, subjects conducted simple task to concentrate on the vibration stimulator corresponding to the visual cue (left or right). We extracted spectral and spatial features using the FFT and Common Spatial Pattern (CSP), respectively. The extracted features were classified using linear discriminant analysis with 10-fold cross-validation. Table 1 shows the optimal stimuli that have the specific frequency and duty-cycle. It also compares the accuracies of the proposed screening method and the accuracies of the normal method. We can see that increases rate of spectral power in our proposed screening method is higher than normal screening method only considering frequency.

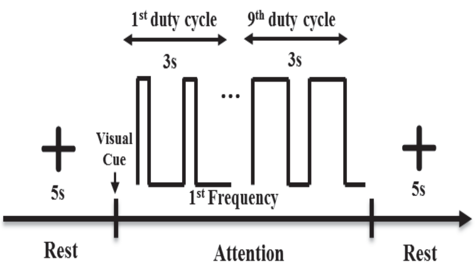

Figure 1. *Illustration of the screening paradigm*

Table 1*. Optimal stimuli and accuracy of two methods*

Sub	Screening method	Frequency (Hz)		Duty-cycle (%)		Increase rate of spectral power (%) (Proposed-Normal)		Accuracy (%)	
		Left	Right	Left	Right	Left	Right	FFT	CSP
A	Normal	15	23	50	50	+17.3	+15.8	66.3	88.7
	Proposed	15	25	90	60			73.2	94.2
B	Normal	23	19	50	50	+10.6	+21.4	50.7	49.3
	Proposed	15	19	70	30			60.3	58.2
C	Normal	25	21	50	50	+17.7	+21.6	77.5	93.2
	Proposed	27	21	70	90			75.4	98.1

Discussion: We found optimal stimuli in the screening session and evaluated performance in the test session. The increase rate of spectral power (attention to rest) in proposed screening method are higher than normal screening method. It means that we need to consider not only frequency, but also duty-cycle in the screening session. Our proposal was to finding optimal stimuli states spin simple methods (FFT). However, we will apply the advanced method such as lock-in analyzer system [1-2] in the future work.

Significance: In this paper, we analyzed the SSSEP responses using the proposed screening method. To our best knowledge, our study is the first investigation for applying the subject-dependent stimuli that have optimal frequency and duty-cycle simultaneously in SSSEP. Hence, the optimized stimulus can be used for SSSEP-based BCI applications with the performance improvement.

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