Proceedings of The 3rd Asian Physics Symposium (APS 2009)
July 22 – 23, 2009, Bandung, Indonesia

Recognizing the Dominant Evoked Potentials Pattern in Human Visual Cortex by Primary Color Stimulation

***Sra Harke Pratama*[1,2], *Suprijanto*[1], *Lulu Lusianti Fitri*[2]**

[1] *Instrumentation and Control Research Group,*
Faculty of Industrial Technology, Institut Teknologi Bandung
[2] *Physiology, Developmental Biology and Biomedical Research Group,*
School of Life Sciences and Technology, Institut Teknologi Bandung
Jl. Ganesha No. 10 Bandung, Indonesia 40132
e-mail address: see_harke@yahoo.com

Abstract

Visual cortex of the human brain plays an important role in processing color stimulation. Nowadays, the electrophysiological processes of visual cortex responses are used in various applications, mainly for medical purposes. This research aims to see how the visual cortex is responding to the primary color stimulations by analysis of the particular patters elicited through brain waves. The responses were recorded using EEG or electroencephalograph in occipital area (O1 and O2). Volunteers were exposed to red-green-blue colors through the projector screen, one second for every color with 20 times repetition. Raw EEG data was then filtered and averaged smoothed using digital signal processing. The results showed that every color has different pattern of evoked potentials. The latencies and amplitudes are found vary among subjects for every color stimulations.

***Keywords*: *Electroencephalography, Evoked Potentials, Event-Related Potential, primary color stimulus, occipital, visual cortex, ERP components*.**

1. Introduction

Some parts of the human brain have been long known responsive to the color stimuli. Three types of primary colors, which are red, green, and blue, were found responding with different latency and amplitude each other(1). It shows that human brain has a different sensitivity toward various color stimulation(2). The main part of the brain that is primarily responding to color stimulation is visual cortex(3), which is used in this study.

One of the devices to measure brain response is electroencephalography or EEG, which use electrical activity of the brain to represent brain response. Using EEG, the detail measurement of latency and amplitude of brain response can be performed by the evoked potentials measurement and analysis which is called ERP(4). ERP is a brain evoked potential that mainly stimulated by specific stimulation at the specific condition(5). ERP is widely used in many researches and has been applied to various applications. One of the prominent purposes using ERP is brain-computer interface, which primary uses a P300 component.

The aim of this study is to know how the visual cortex of human brain is responding to the primary color stimulation. Evoked potential components such as P300 became the parameter to evaluate the particular pattern of visual cortex's responses by each of color stimulation.

2. Methods

Five participants, which were ITB undergraduate students, aged 20-23 years (all male) with normal or corrected-to-normal vision and no history of neurological or psychiatric disorders, were used as subjects. Three primary colors, which are red, green, and blue, were used as the stimuli. The appearance of colors was arranged with composition of 100% based on Microsoft Power Point 2003.

Two gold electrodes were used at the locations of O1 and O2 to represent visual cortex. Electrodes placing based on 10/20 International System. All the data taking process were done in a room with illumination of 1 Lux.

Stimulation process was consisted of three sessions. At the first session, red stimulus was used for 20 times repetition with one second length for each single stimulation and 3-5 seconds of rest between repetitions. The second (green) and third (blue) sessions used the same procedure as the first, with the 4-5 minutes rest between sessions.

The data were saved with 256 sampling rate. Before the data of each session and location were averaged, every repetition data was manually evaluated to rejecting data with artifact. In fact, about 20% of the data were rejected. The averaged data then were processed by filtering and smoothing average. The whole raw data of one person in one session were also averaged to use as the base line.

Data analysis was separated into two steps. First, latencies of minimum and maximum amplitudes in all participants were recorded, then grouped based on color, electrode location, and polarity. Each group of color and electrode location then was analyzed using ANOVA One-Way. The results also showed the various ERP components detected in this research.

The second step was based on the ERP components resulted by first step analysis. The dominant components were further analyzed by grouping every three or four times repetitions. Each group was averaged. In fact, in one session for one color the data were separated into four part of trial, since it was 20 times repetition and 20% of rejected data. At this step, the amplitudes of the selected components were also counted. To see the significance correlation of latencies and amplitudes of each component, ANOVA One-Way analysis had also performed.

3. Results and Discussions

The particular aim of the analysis is to see whether the latencies and amplitudes among subjects have a similar values or significantly different in three different primary color stimulations. The similar latency among subjects may suggest general value of latency or latency interval that is tightly related to the basic function of the brain. It can be used as parameter to generalize latency values. Once it is generalized, it would have a steady value that more recognizable while being discovered.

Figure 1 shows the evoked potential responses in O1 and O2 by red, green, and blue stimulations after averaged of around 20 repetitions. Qualitatively, all graphics shows that every subject has a high variability in response of color stimulation. In spite of it, there are some peaks in each graphic which are disposed similar of latency as well as amplitude in all subjects. The similarities predominantly can be found at around 300 ms latency of positive peaks in every graphic and around 200 ms and 450 ms latency of negative peaks in some graphics, although at the 450 ms latency, the similarity becomes lower. It means that at those spots, subjects' visual cortex was responding similarly to the each color stimulation. This similarity gives the argument that the 300 ms latency of positive peak or popularly called P300 can be used to represent the ERP response of visual cortex. The 200 ms latency of negative peaks, which is called N200, also suggests being one of the ERP components that represents response of visual cortex in color stimulation.

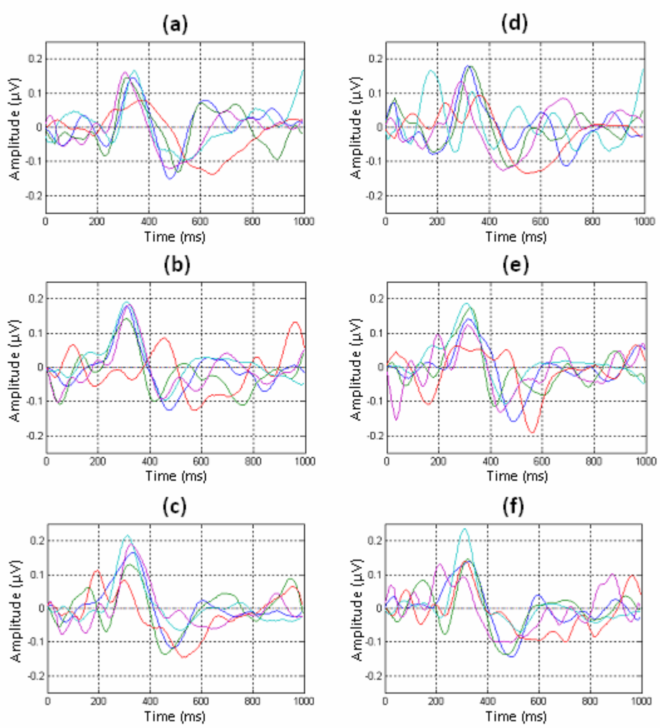

Figure 1 Evoked potential responses in O1 by stimulations of (a) red, (b) green, (c) blue, and in O2 by stimulation of (d) red, (e) green, and (f) blue. Each color on every graphic represents each subject.

The latencies and amplitudes in some graphics show a quite similarity of P300 and N200. In (a) and (b), four of five subjects disposed have a high similarity in latencies and amplitudes of P300, but varies in N200. Meanwhile, the P300 in (c), (e), and (f) seem similar in latencies but vary in amplitudes, but varies for both latencies and amplitudes in N200. In (d), both P300 and N200 are found vary in latencies and amplitudes for all subjects.

The results above mean that the subjects' O1, which represents the left visual cortex, disposed response red and green stimulation in uniform pattern of P300. In contrary, the unstable pattern of both P300 and N200 is showed by the subjects' O2 that represents right visual cortex when red and green stimulations. The difference between O1 and O2 response of P300 give a suggestion that the left visual cortex of the subjects have a better recognizable P300 pattern than right visual cortex in red and green identification. In addition, P300 in O1 and O2 also have the stable pattern to recognize during red and green stimulation. These conclusions are only valid when using plenty repetitions.

The blue stimulation cause both O1 and O2 of the subjects similar in latencies but varies in amplitudes of P300. It means that both left and right visual cortex have a quite same response during blue stimulation. In contrary, the latencies and amplitudes of N200 are varies not only during blue stimulation but also red and green stimulation. This result indicates that P300 is more recognizable in latency during blue stimulation but not varies between O1 and O2. The result is also only valid when using plenty repetitions.

Table 1 and 2 use three latency parameters, which are N200, P300, and the different value of N200 and P300 (Diff.). The analysis of both tables based on the second step in methods chapter, which broke repetitions into four groups for each subject in each electrode location. The use of N200 and P300 for further analysis is based to first step results that are represented in Figure 1. In some graphics, some peaks of P300 and N200 are seemed inconsistently similar with other curves, while the distance between both peaks latencies as well as amplitudes is consistent. Due to former statement, the distance of P300 and N200 (Diff.) is suggested to be analyzed to see whether it provides the alternative path to recognize the pattern or not.

Table 1 P-values of latency among subjects

		Latency		
		N200	P300	Diff.*
Red	O1	0.637	0.509	0.196
	O2	0.017	0.438	0.296
Green	O1	0.207	0.963	0.250
	O2	0.049	0.956	0.018
Blue	O1	0.046	0.681	0.005
	O2	0.336	0.024	0.004

*Diff.: Different latency value of P300 and N200

Table 1 shows diverse P-values of latency among subjects by ANOVA One-Way analysis, based on the second step in the methods section. During red stimulation, it is showed that N200, P300, and Diff. latencies are not significantly different ($P > 0.05$) among O1 of all subjects, while N200 is significantly different ($P < 0.05$) in O2. The similar results in O1 are also found during green stimulation, while N200 and Diff. are significantly different in O2. In contrary, the results during blue stimulation show less similar latencies among subjects for both electrode locations. There are only latencies of P300 in O1 and N200 in O2 which are not significantly different among subjects.

The result indicates that each of three colors has a particular pattern to generalize. Overall, P300 latencies are more recognizable than N200 and Diff., which indicates the latency-based general pattern of P300 in primary color stimulation is a part of brain process to recognize color. Red also becomes the most recognizable color compared to other two, while blue becomes the less because its stimulation affects inconsistent latency among subjects.

Table 2 P-values of amplitude among subjects

		Amplitude		
		N200	P300	Diff.*
Red	O1	0.339	0.077	0.048
	O2	0.728	0.174	0.258
Green	O1	0.162	0.024	0.298
	O2	0.498	0.038	0.241
Blue	O1	0.025	0.159	0.500
	O2	0.126	0.147	0.028

*Diff.: Different amplitude value of P300 and N200

Table 2 shows ANOVA One-Way statistical analysis of amplitudes among subjects. It is shown that during red stimulation, the N200 and P300 amplitudes of all subjects are not significantly different, as well as the Diff. in O2. The different tendency is found during two other colors. During green stimulation, the N200 and Diff. amplitudes are not significantly different while P300 amplitudes are significantly different among subjects. Blue stimulation affects more diverse results, which the significant different results are found differently.

The diverse results above indicate that both left and right visual cortex response each color differently. It means that beside latency, there is a different response in amplitude among subjects. Disparate with the latency, N200 amplitudes are more general that P300. Amplitudes are more recognizable during red stimulation in both electrode locations, while green stimulation can be recognize without identification its affect in P300 amplitude. Similar with the latency, blue stimulation affects inconsistent amplitudes of N200 and Diff. in both electrode locations.

The diverse results between latency and amplitude analysis in Table 1 and 2 give more complex of indication in how to recognize primary colors. It also provides a different approach to recognizing primary colors if compared using a whole-averaged repetitions, which the latter are represented in Figure 1. The diverse results between a whole-averaged repetitions and statistical analysis in both tables above show that even with the same procedures and stimulus characters, the results among subjects still vary between four groups of repetitions.

These results insist to provide more detail procedures to obtain more particular pattern of P300 and other components on the next studies. However, for more particular purposes in using P300 such as BCI, the methods must be upgraded than the used in this research. The more specific methods such as oddball paradigm should be applied to elicit more particular specifications of P300(6).

4. Conclusion

Visual cortex of all subjects' responses varies during the stimulation of red, green, and blue. P300 and N200 are found as dominant evoked potential components during stimulations. Both components also statistically varies on latency and amplitude in each color as well as in electrode locations, indicates each color stimulates a specific pattern in subjects' visual cortex, mainly in P300 and N200. To obtain more particular pattern characteristics of P300 and N200 by color stimulations, specific procedure and color stimulus should be applied for the next studies.

References

1. Kinney, J. A. S., McKay, C. L., Mensch., A. J., & Luria., S. M. 1972. Techniques for analysing differences in VERs: colored and patterned stimuli. *Vision Research*, **12**: *1733-1747*
2. Wojnicki, P. 2004. Quantification of Image Colorization with Visual Evoked Potentials and Functional Magnetic Resonance Imaging. *Ph.D Dissertation*. University of Medicine and Dentistry, New Jersey
3. Goebel, R., Muckli, L., & Kim, D. 2004. Visual system. *In: G. Paxinos dan J. K. Mai, eds. The Human Nervous System, 2nd Ed. New York: Elsevier Academic Press.*
4. Fabiani, M., Gratton, G., & Federmeier, K. D. 2004. Event-Related Brain Potentials: Methods, Theory, and Applications. *In: Todd C. Handy, ed. Event-Related Potentials: Methods, Theory, and Applications. Cambridge: The MIT Press*
5. Cacioppo, J. T., Tassinary, L. G., & Berntson, G. G. 2007. *Handbook of Psychophysiology. New York: Cambridge University Press*
6. Sellers, E. W. 2004. A P300-Based Brain-Computer Interface: Testing an Alternative Method of Communication. *Ph.D dissertation*. University of South Florida