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Event Related Potentials in terms of Visual and Auditory Stimuli

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***Abstract*—**Event-related potential (ERP) is one of the useful tools for investigating cognitive reactions. In this study, the potential of ERP components detected after auditory and visual stimuli was examined. Subjects were asked to respond upon stimuli that were of three categories; Target, Non-Target and Standard stimuli. The ERP after stimulus was measured. In the experiment of visual evoked potentials (VEPs), the subjects were asked to gaze at a center point on the monitor screen where the stimuli were provided by the reversal pattern of the checkerboard. In consequence of the VEP experiments, we observed consistent reactions. Each peak voltage could be measured when the ensemble average was applied. Visual stimuli had smaller amplitude and a longer latency compared to that of auditory stimuli. The amplitude was the highest with Target and the smallest with Standard in both stimuli.

***Keywords*—**Auditory stimulus, EEG, event related potential, oddball task, visual stimulus.

I. Introduction

RECENTLY, the study of brain such as brain activities and cognitive science is rapidly developing. The American daily newspaper, The New York Times, predicted that the 21st century will be the era of cognitive science rather than the age of internationalization [1].

Electroencephalogram (EEG) has the advantage of higher time resolution than other methods such as MRI and PET. Especially ERPs are known as one of the efficient methods to understand human cognitive activities. P300, N400, P600, contingent negative potential etc. are determined through internal cognitive processes. There are also ERPs generated by external stimuli [2].

A number of previous studies have been carried out to observe brain activities following cognitive activities and stimuli as well as to monitor the subsequent responses based on specific events [3]-[8]. In addition, there are previous studies that looked at potentials occurred even before stimuli [9]-[14]. Since the ERPs are observed not only after but even before stimulation, in general, it will be interesting to note the ERPs before and after the event in order to grasp human cognitive processes.

In this study, however, the ERPs after stimuli were measured and examined upon visual and auditory external events. It is hypothesized that the ERPs are observed upon random stimuli and the components of the ERPs may be varied depending upon the type of simulation.

A. Oddball Task

It was reported that a random single stimulus in the Oddball Paradigm could easily induce P300 [3]. Oddball Paradigm is the method used to get the P300. Two stimuli are presented randomly, one stimulus being a less frequent stimulus than the other. The number of the target stimulus is less than that of the standard stimulus, and the event used to obtain the P300 becomes the target stimulus. The subject under experiment should identify the target in the Oddball Paradigm. Normally, pressing the button identifies the timing when the target has been identified [3], [4]. In this paper, the 3-Oddball paradigm was used for visual ERP experiments and the 2-Oddball paradigm was adapted for auditory ERP measurements. The 3-Oddball paradigm is a combination of target and standard stimuli, along with distracting stimuli that interfere with target stimuli [4].

B. P300 and N400

P300

When P300 is experimented with the Oddball paradigm, positive potential is generated around 300 ms after presentation of target stimulus. This is called P300. Usually P300 is known to be related to 'cognition' and 'perception' [2], [5].

N400

N400 is a negative potential observed between 200 and 600 ms after stimulus or event presentation, which was first described as a response to words whose meaning became different in separate sentences [7]. The N400 also describes the process of finding specific information from old memories [2].

C. Visual Evoked Potential

VEPs generated by the visual pattern stimulus are transmitted from the retina to the optic nerve, optic chiasm, optic tract, lateral geniculate body, optic radiation and finally to primary visual cortex. VEPs are used to examine the pathological lesion [15].

II. Experimental Methods

A. Participant

The subjects were three college students with no neurological and psychiatric disorders. All subjects were right-handed, two males and one female.

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B. Stimulus

Visual stimulus is a 3-Oddball Task, which consists of three stimuli. The stimuli are designated as 'X' (target), 'H' (non-target) and 'O' (standard) with probabilities 0.1, 0.1, and 0.8 respectively. The total number of stimuli is 350. 35, 35, and 280 frequencies are presented to the subjects respectively. The subject should press the keyboard button when the 'X' (target) stimulus is presented. The order of stimulation was arranged by randomly generating three stimuli using the random variable generator of the Excel program. The stimulation was given at intervals of 2 seconds, and each stimulus was displayed for 68 ms.

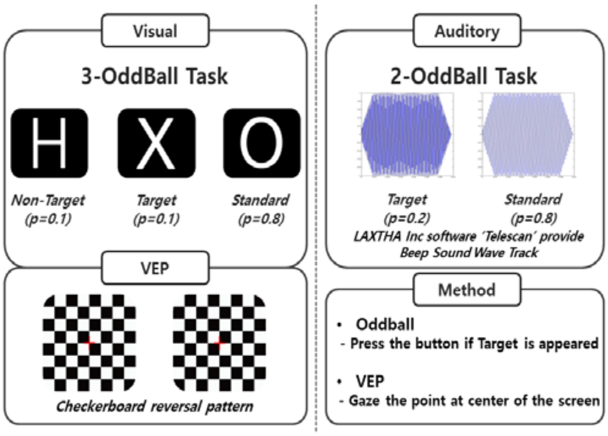

Fig. 1 Patterns of visual and auditory stimuli

As shown in Fig. 1, the stimulus of the 2-Oddball Task corresponding to the auditory stimulation consists of two kinds. The stimulus is Beep_Sound 1 (Target, 2 kHz tone) and Beep_Sound 2 (Standard, 1 kHz tone) provided by Laxtha Inc., Daejeon, Korea. The two stimuli have probabilities of 0.2 and 0.8, respectively. The total number of stimuli is 270 where 54 is the number of the target stimulus and 216 is that of the standard stimulus. The subject should press the keyboard button when the 2 kHz tone stimulus is given. The subjects were wearing earphones. The left and right volumes had the same amplitudes. The order of stimulation was arranged by randomly generating the two stimuli in random order using Excel's random adder generator. The stimulation interval was two seconds.

A part of one's field of vision can be stimulated by looking at a constant size grid. The monitor shows checkerboard reverse patterns as in Fig. 1 and provides the VEPs. The overall monitor size can be viewed as a field of view, and the reversal pattern was about the same size as a checkerboard size of 8x8-20'x24'. A black and white lattice was used and a red cross was placed in the center of the screen in order to fix the eyes. The stimulation rate was 2 times reversal per second. The total stimulus was 200 times and the ensemble average was 137 times.

C. EEG Measurements

Visual Stimulation

In order to measure ERPs, QEEG-8^{TM} (Laxtha Inc., Daejeon, Korea) was used. The bandpass filter frequencies were 0.6 ~ 46 Hz and the sampling rate was 512 Hz. To reduce the impedance between the electrode and the scalp, Nuprep^{TM} gel was used prior to the electrode attachment.

The positions of the electrodes were set to Fp1 and Fz (frontal lobe), C3, C4 and Cz (central lobe), P3, P4 and Pz (parietal lobe) based on the International 10-20 System. The reference electrode was attached to the right earlobe and the ground electrode to the forehead. Epoching was performed between -200 msec and 800 msec from the time of stimulus (Target, Non-Target and Standard) as a reference point.

Auditory Stimulation

The electrode positions were Fz (frontal lobe), Cz (central vertex), Pz (parietal lobe) and the reference and ground electrodes were attached to both mastoids. The experiment was carried out with eyes closed. Target (Beep_Sound 1, 2 kHz tone) Epoching was performed between -200 msec and 800 msec from the time of audio sound as a reference point.

Visual Event Potential

The electrode positions were Oz, O1 and O2 (occipital lobe), T4 and T5 (temporal lobe). The reference electrode was attached to the center of the forehead and the ground electrode to the right ear bone. The experiment was carried out with eyes open.

D. Procedure

The subject sat comfortably in the chair. The distance from the monitor was 60 cm. For each of the three experiments stated in the above, an experimental administrator explained about the objectives, procedures and methods of the experiment. In the Oddball Task, the subject responded to the target stimulus by pressing the button as quickly as possible. During the VEP measurements, the subject was asked to take a look at the center of the monitor.

Before the administrator began the experiment, a signal was given as to whether the subject was ready to start the experiment. During the experiment, if the subject felt abnormality or the manager judged that external factors influenced the experiment and the experiment was not performed properly, the experiment was stopped and resumed after a sufficient time.

E. Data Analysis

Data were analyzed using the MATLAB^{TM} EEGLAB (Version 13_6_5b). The EEGLAB is an open source program from the UC San Diego SCCN (Swartz Center for Computational Neuroscience) and provides a variety of toolboxes that are widely used in EEG analysis. Before analyzing the data, the signal processing to remove unnecessary noise from raw data was performed. Notch Filtering, Independent Component Analysis, Baseline Removal, Moving Averaging, Artifact Rejection, and Down Sampling provided by the EEGLAB were applied. The ensemble average was done for analysis [16].

III. Results

A. ERPs of Visual Stimulus

Fig. 2 shows one experimental result. The solid line indicates for Target stimulus. The dash line represents for Non-target stimulus and the dim dash-dot illustrates Standard stimulus.

In Fig. 2, the peak and latency of P300 and N400 are seen clearly. The time analysis of P300 was set within a period of 200 ms and 500 ms. Fig. 3 shows the peak amplitude and latency of P300 for the individual whose ERPs are shown in Fig. 2. The electrode locations were at the central and parietal lobes. The results show that there are differences in the amplitude and latency between Target and Non-target responses.

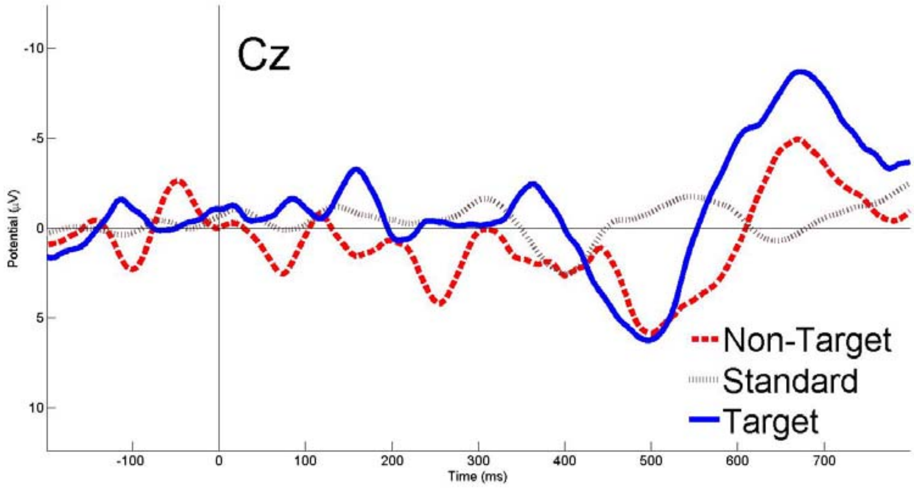

Fig. 2 ERPs at Cz induced by visual stimulus

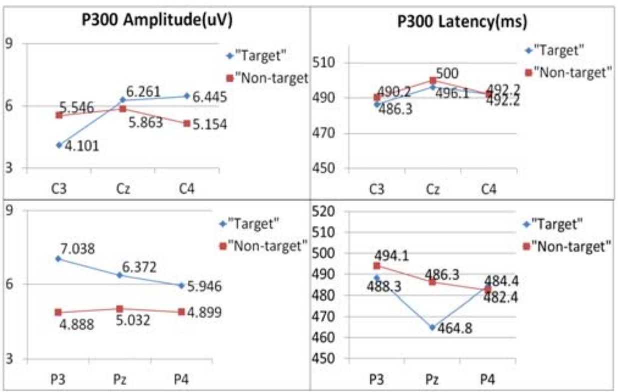

Fig. 3 Visual ERPs at the central and parietal lobes in terms of P300 amplitude and P300 latency

The results of P300 for the three subjects were averaged and summarized in Table I. The amplitude of P300, which is known to be 'target' in the study subjects, is the largest, and the amplitude becomes smaller in the order of Non-Target and Standard. In addition, it was shown that the latency time was the largest for Target ('X') and the smallest for Standard ('O').

The analysis time of N400 was set to be between 400 ms and 700 ms from the stimulus time. Table II shows the mean value of N400 analyzed for Target ('X'), Non-target ('H') and Standard ('O') of three subjects. In this table, when comparing the amplitude and latency period for each stimulus, it is seen that the target amplitude is the largest and the standard amplitude is the smallest. In terms of the latency period, Standard stimulus is the fastest.

TABLE I
Total Average of ERPs from Visual 3 Oddball Task for P300

Channel	Target('X') (N=35)		Non-Target('H') (N=35)		Standard('O') (N=280)	
	Peak (uV)	Latency (ms)	Peak (uV)	Latency (ms)	Peak (uV)	Latency (ms)
Cz	5.61	438.17	4.23	442.07	3.06	356.77
Fz	4.98	444.67	5.40	456.37	3.72	425.13
Pz	5.79	432.27	3.29	404.93	3.20	341.13
P3	5.71	404.93	3.71	348.27	3.55	336.57
P4	5.76	438.13	3.69	345.03	3.90	337.90
C3	4.21	439.47	4.03	383.43	2.48	363.27
C4	6.06	439.43	3.67	388.67	3.40	356.10

TABLE II
Total Average of ERPs from Visual 3 Oddball Task for N400

Channel	Target('X') (N=35)		Non-Target('H') (N=35)		Standard('O') (N=280)	
	Peak (uV)	Latency (ms)	Peak (uV)	Latency (ms)	Peak (uV)	Latency (ms)
Cz	-10.8	622.40	-6.48	632.17	-2.57	587.87
Fz	-9.20	618.50	-6.38	654.30	-3.79	615.20
Pz	-10.8	623.70	-4.83	612.53	-2.58	525.40
P3	-10.1	625.00	-4.91	606.10	-2.16	529.27
P4	-9.08	639.33	-4.91	614.60	-2.53	533.20
C3	-10.8	624.33	-7.66	633.50	-3.29	583.97
C4	-8.92	641.93	-4.22	630.90	-2.37	598.93

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B. ERPs of Auditory Stimulus

Fig. 4 is the results of expressing the ERP by auditory stimulus as scalp image. This figure is the result for one of three subjects and is the ensemble average between -200 ms and 800 ms induced by Beep_Sound 1 (Target). Fz, Cz, and Pz are along the same axis, and scalp images are displayed for the corresponding points. Fig. 4 shows how the amplitude changes within the P300 and N400 analysis ranges. The abscissa is the potential (uV) and the ordinate is the epoching time (from -200 ms to 800 ms).

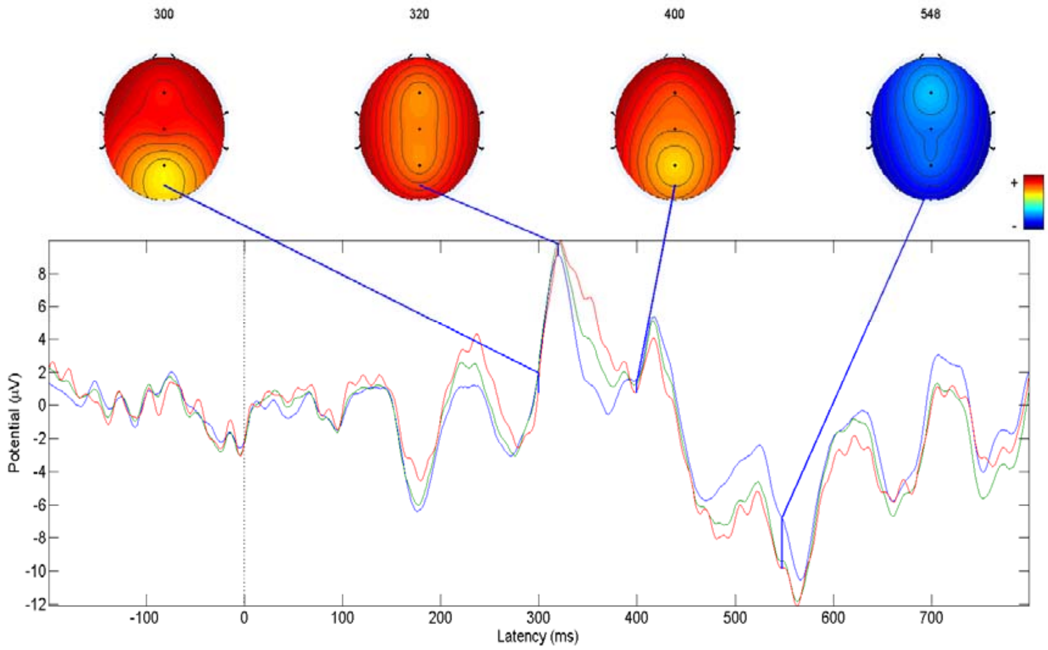

Fig. 4 Auditory ERPs

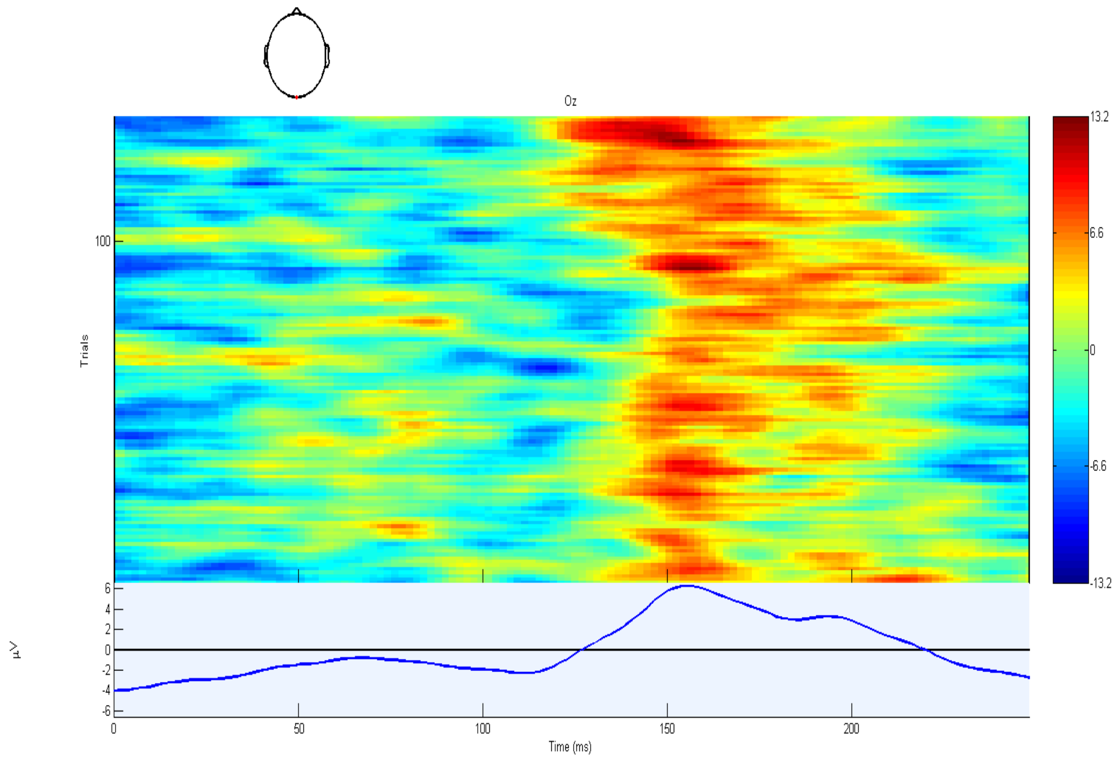

Fig. 5 Graphical display of VEPs

Table III summarizes P300 potentials and latencies of three subjects. The analysis time of P300 ranged from 250 ms to 450 ms after the stimulus time.

TABLE III
TOTAL AVERAGE OF ERPS FROM THE AUDITORY 2 ODDBALL TASK FOR P300 WITH 54 TARGET STIMULI

Channel	Peak (uV)	Latency (ms)
Fz	13.21	330.7
Cz	12.75	329.4
Pz	12.20	358.7

The value and latency of N400 were measured and the mean values of the three subjects were presented in Table IV. The analysis time of N400 was between 350 ms and 550 ms from the stimulus time.

TABLE IV
TOTAL AVERAGE OF ERPS FROM THE AUDITORY 2 ODDBALL TASK FOR N400 WITH 54 TARGET STIMULI

Channel	Peak (uV)	Latency (ms)
Fz	-7.77	542.3
Cz	-8.32	541.0
Pz	-10.26	541.6

Comparing P300 and N400 between visual and auditory stimuli, the auditory ERP showed large amplitude and short latency in general.

Fig. 5 is a graph obtained by performing an ensemble average of 137 times at the Cz electrode position as a result of the VEP test. The amplitude of ERPs in the unit of uV was pseudo-colored where the red color represented higher magnitude. The horizontal axis indicates the time from 0 (stimulus time) to 250 ms and the vertical axis is trials. It can be seen that a positive peak is obtained at around 150 ms.

IV. DISCUSSIONS

The goal of this study is to understand the brain activities in terms of time when visual and auditory stimuli are given and to use them in various applications. Therefore, this study has examined the major components of the ERPs after stimulation and examined whether there is any difference depending on the type of stimulus. And it was observed that there is a difference between the amplitude and latency for the ERPs of visual and auditory after the stimulus is presented. In addition, we tried to find out the difference from the ERPs through the VEP experiment.

In previous studies, the auditory P300 was smaller than the P300 of the visual acuity and the latency was shorter [4], [8]. In this study, when comparing P300 of visual and auditory, the latency of auditory was shorter than that of visual. The same observation was made compared to the previous studies. However, in this study, the amplitude of auditory stimulus was larger than that of visual stimulus. The difference compared to the previous study is that the subject in this study closed the eyes in the auditory ERP test. In other words, it may be speculated that the amplitude of the ERP becomes larger when the eyes are closed during the experiment.

Although previous studies have discussed P300, additional information is available for the N400. In this study, N400 after P300 were detected in a range of 200-600 ms. For all three subjects, the N400's amplitudes were consistently decreased in order of Target, Non-target and Standard. The visual ERP experiment can be interpreted as follows; there were consonants at the center of the monitor and there were not enough words to interpret the meaning, therefore N400 amplitudes became larger [7].

The ERP and the VEP were different in terms of how measured data are interpreted. The VEP shows a certain response in each trial when the stimuli showing pattern are given. This would imply that there is a region that is constantly responsive to the path of vision. The ERP shows the internal state of the brain related to a specific event. Through the process of averaging the activities of the brain 'recognition', and the components of the EEG unrelated to the stimulus in the time axis disappear and the EEG components related to the stimulus become the shape of the potential that we want to see.

This study compared ERPs by visual and auditory. The main components of the ERP after stimulation were discussed. Comparing with the VEP, we could see the difference between the evoked potential and the ERP. Based on the previous research [9]-[12], in the future, it will be interesting to study specific potentials even before stimulation or event is given in order to deepen the study of human cognitive activities.

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