Relation between Auditory Stimulus Intensity and Response of P300 with Eyes-Opened and Eyes-Closed State

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Abstract

For the purpose of examining how the auditory stimulus level and the eyesight have a mutual influence on ERP, we tried to investigate the relation between auditory stimulus level and latency of P300 with eyes-opened (EO) and eyes-closed(EC) state. Two auditory stimulus levels are selected as high-intensity(HI;80dBNHL) and low intensity (LI;10dBNHL). It has been regarded that the latency of P300 became longer as the auditory stimulus level decreased while the latency was not so different between EO and EC. However, we found that the latter did not always hold true though the former coincided with our experimental results. The latency at HI tended to be longer comparatively with EO, while in the case of LI the latency was longer with EC. Consequently, the latency variation resulting from the change of stimulus level with EC was larger than with EO. In this paper, we evaluated this phenomenon more quantitatively.

keyword: ERP, latency, P300, intensity, eyes-opened and eyes-closed

1 Introduction

ERP(event related potential) is expected to be objective and quantitative indicator of mentality and activity of brain such as recognition, judgment, expectation. Among many kinds of ERP, P300 is especially useful and studied in many fields since it appears about 300 ms after stimulus and has a larger amplitude than the others. For example, it is said that P300 latency is getting longer as senile dimentia makes progress. And relation between P300 and mental state such as recognition and judgment is investigated in the field of psychology[1].

In this work, for the purpose of examining how the auditory stimulus level and the eyesight have a mutual influence on ERP, we tried to investigate the relation between auditory stimulus level and latency of P300 with eyes-opened and eyes-closed state. So far many reports say that latency of P300 becomes longer as sound pressure level or hearing level decrease [2],[3].

We found that variation or difference of latency caused by changing stimulus level was significantly larger with eyes-closed state than the eyes-opened state. In this paper, we evaluated this phenomenon more quantitatively by examining the relation between auditory stimulus level and latency of P300 with eyes-opened state and eyes-closed state.

2 Method

As a beginning , let us describe the experimental condition. The auditory stimulus are given to subjects through headphones. Waveforms of ERP were recorded by way of monopole or montage with reference to averaged ear-indefferent potential. In the following experiment, we applied the relatively simple task called 'odd ball' paradigm. In this paradigm, we used two kinds of single tone burst, namely, 2kHz and 1 kHz as stimula which were presented to subjects at random sequences but at the constant ratio, that is, 20:80. Subjects were instructed to press the button when 2kHz stimulus was recognized. The 2kHz stimulus with task is refered to as 'target', while the 1kHz stimulus without task is called 'non-target'.

It is said that P300 appears more dominantly for the target stimulus than non-target about 300 ms after stimulation. However, the appearance of P300 not only depends on the mentality of subjects such as habituation, fatigue, judgment and recognition, but also is influenced by background waves. These cause the fluctuation of amplitude and latency. Consequently it is difficult to precisely estimate the evoked potential from a single trial response. Therefore, waveform of ERP are usually estimated by summing up a large number of responses to reduce the background wave and noise components. Then maximum amplitude of each component such as P300, and its latency at the maximum point are measured.

We also employed this method for the data analysis. Stimulus interval was set at 2 seconds and data was measured for 5 to 6 minutes, which means that about 30 responses for 'target' stimulus were recorded for each condition. We examined the latency of P300 on the four conditions, that is, combination of two stimulus levels at

high intensity (HI,80±10dbNHL) and low intensity (LI,10∼15dbNHL)(LI is selected as the lowest intensity which the accuracy for the response to task was more than 97.5%.) and two subject's condition, that is, eyes-closed and eyes-opened state as described in the following paragraphs.

3 Result

Eleven subjects with normal auditory sense were examined in this experiment. They are aged 22 to 36 years (ave=25.6, s.d=4.4) and 9 of them are male. First, higher frequency components of the measured signals were eliminated by low pass filter (LPF) with cut off frequency of 60 Hz. Then 'target' responses were averaged separately for each electrode and condition. In averaging 'target' responses, we observed EOG as well as ERP to check whether any artifact by blink did not mix with ERP. Latency and variation of latency defined by Eq.(1) were obtained.

$$l_{variation} = l_{low} - l_{high} \quad (1)$$

l_{low} : latency with low level stimulus
l_{high} : latency with high level stimulus

Figure1 shows the relation between latency with their eyes-opened (EO) and closed (EC) in the case of low intensity stimulus(LI). The case of high intensity stimulus(HI) is similarly shown in Fig2. Figure3 shows the relation between variation of latency with EC and that with EO. In each figure, 44 data , that is, combination of 11 subjects with 4 electrodes are plotted. It is interesting to note that in the case of LI the latency with EC tends to be longer than that with EO (Fig1), on the contrary in the case of HI the latency with EC is shorter than EO (Fig2). As the result, in terms of the latency variation caused by difference of stimulus level, the value with EC is clearly larger than that with EO as shown in Fig3. To make this relation more clear viewpoint, mean latency for LI was obtained by averaging all data plotted in Fig1, and that for HI was obtained from Fig2, then, Fig4 shows the variation of mean latency from HI to LI. For both electrodes, Fz and Pz, mean latency with EC changes much more than EO.

In order to evaluate the above results more quantitatively, we used T-test between two groups. Table1 shows mean and S.D of latencies and results of T-test for latencies between EC and EO in the case of LI for each electrode based on mean and standard deviation of latency.

Values in column 'T-test' indicate possibility that two samples for EC and EO belong to the same population. Whether these distributions are significant or not by 95% reliance section is indicated by '◯' or '×' in the column 'significance'.

The Mean, S.D and results of T-test between latencies with EC and EO for HI are similarly shown in Table2. Moreover, Table3 shows the obtained latency variations due to the change of stimulus intensity. In case of LI any significant diference in latency between EC and EO is not indicated(Table1), but in case of HI the significance is indicated except Oz(Table2). There is also the significant differnce in latency variations between EC and EO(Table3).

Finally to compare above results with conventional processing, parameters measured from the waveform averaged over all subjects were similarly analyzed. Figure5 to Fig8 show the waveform obtained by averaging more than 300 target responses over all subjects without the LPF to eliminate alpha wave.

It can be seen from Fig5 to Fig8 that EOG does not corrupt ERP and as a result of the adequate experimental environment the signal-to-noise ratio of data is enough high to attain reliably processing.

The latency of P300 component of averaged waveform are shown in Table4 and Table5.

Regarding the latency, the value with EC is larger that with EO in the case of LI(except for Oz), while the relation is reversed in the case of HI.

We may say that results based on averaged waveform show almost the same tendency as those obtained for individual subjects. These results are summarized as shown in Table6.

4 Conclusion

There are many reports in former studies that longer latency and smaller amplitude of P300 are accompanied with lower sound pressure level(SPL) or normal hearing level(NHL) [2],[3]. We also got the same result in comparison with high intensity(HI) and low intensity(LI).

To check reliability of the data in our experiment we confirmed that no trace of sleeps was observed in experimental recording and response ratio was more than 97.5% in terms of accuracy. There was no significant difference between eyes-opened and eyes-closed state and response time.

The latency of EC was shorter than EO with HI. And with LI, latency of EO was longer than EC, but there was no siginificant difference($p<0.05$). On the other hand, the latency variation of EC from LI to HI is longer than EO siginificantly($p<0.05$).

More detailed investigation on the relation between latency and stimulus level through the measurement for various intensity is work in progress.

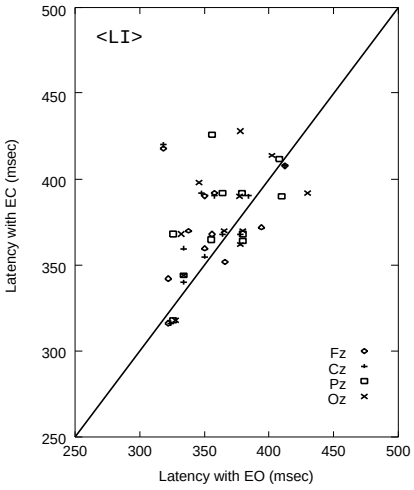

Fig1. Relation between latency with EO and EC in the case of LI.

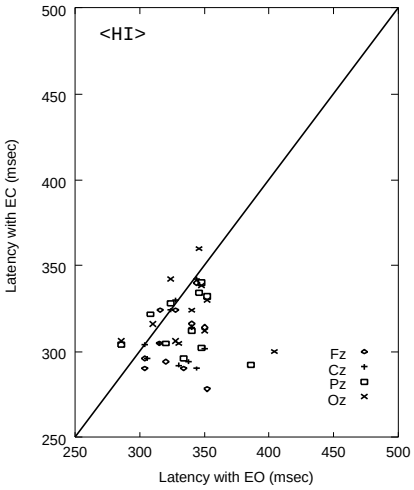

Fig2. Relation between latency with EO and EC in the case of HI.

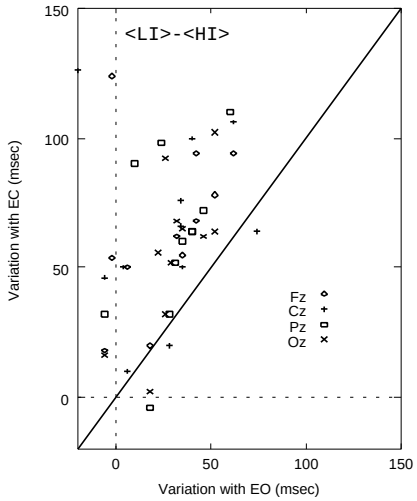

Fig3. Relation of latency variations between EO and EC.

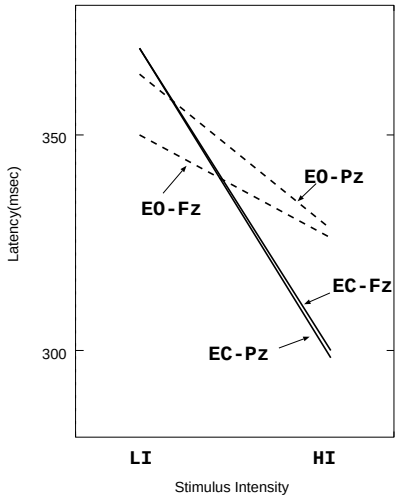

Fig4. Change of mean latency between LI and HI.

Table1. Mean, SD of latencies and results of T-test(significance) for latencies between eyes-opened(EO) and eyes closed(EC) state in the case of low intensity stimulus(LI) for each electrodes..

Electrodes		Fz	Cz	Pz	Oz
$mean \pm SD$	$opened(EO)$	353 ± 28	355 ± 27	365 ± 28	368 ± 30
$[msec]$	$closed(EC)$	372 ± 28	373 ± 29	376 ± 29	378 ± 30
T-test(significance)		0.16(X)	0.16(X)	0.40(X)	0.49(X)

Table2. Mean, SD of latencies results of and T-test(significance) for latencies between EO and EC in the case of high intensity stimulus(HI).

Electrodes		Fz	Cz	Pz	Oz
$mean \pm SD$	$opened(EO)$	328 ± 17	329 ± 15	336 ± 25	338 ± 28
$[msec]$	$closed(EC)$	307 ± 18	309 ± 16	315 ± 16	322 ± 18
T-test(significance)		0.012(◯)	0.0073(◯)	0.043(◯)	0.14(X)

Table3. Mean, SD of latency variations defined by Eq.(1) and results of T-test(significance) for latency variation between EO and EC.

Electrodes		Fz	Cz	Pz	Oz
$mean \pm SD$	$opened(EO)$	26 ± 22	28 ± 26	31 ± 15	31 ± 14
$[msec]$	$closed(EC)$	65 ± 30	65 ± 34	61 ± 31	56 ± 28
T-test(significance)		0.0037(◯)	0.012(◯)	0.015(◯)	0.024(◯)

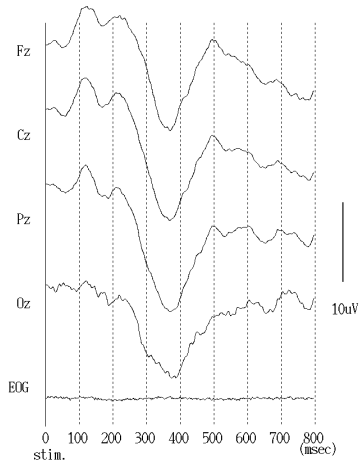

Fig5. Grand averaged waveforms using all subjects' target responses with EC in the case of LI.(381 responses)

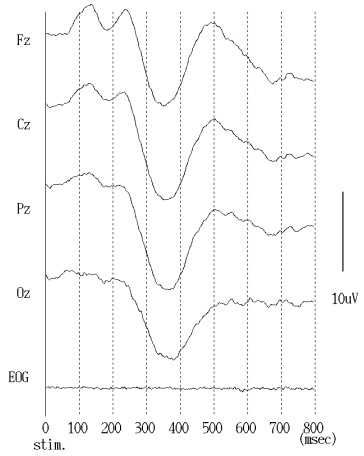

Fig6. Grand averaged waveforms using all subjects' target responses with EO in the case of LI. (309 responses)

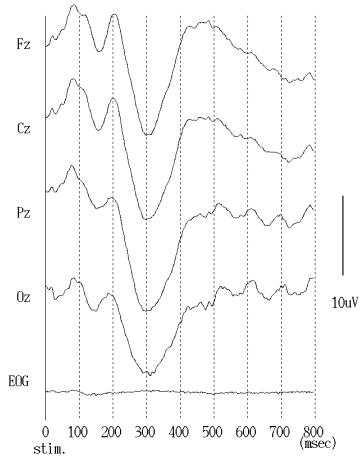

Fig7. Grand averaged waveforms using all subjects' target responses with EC in the case of HI. (300 responses)

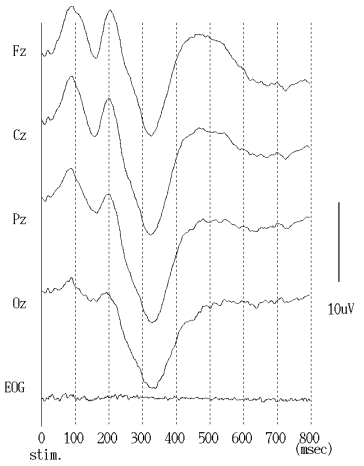

Fig8. Grand averaged waveforms using all subjects' target responses with EO in the case of HI. (361 responses)

Table4. Latency of grand averaged waveform with EC in the case of LI.

Electrodes		Fz	Cz	Pz	Oz
Latency	*opened(EO)*	350	354	364	380
[*msec*]	*closed(EC)*	370	370	370	374

Table5. Latency of grand averaged waveform with EC in the case of HI.

Electrodes		Fz	Cz	Pz	Oz
Latency	*opened(EO)*	326	324	328	338
[*msec*]	*closed(EC)*	300	298	298	312

Table6. Summary of results

	Latency
LI	EC $\geq$ EO
HI	EC $<$ EO
Variation	EC $>$ EO

References

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