

# **USABILITY OF EEG SIGNALS FOR FES CONTROL -through Event Related Potentials Caused by Obscure Pictures-**

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## SUMMARY

The goal of this report is to consider the usability of change of human event related potentials characterize when they watch some obscure pictures and judge the normality of the pictures. To reach the goal, a model is considered and simulations are done on the model, the characters are clarified by the results of the simulation and we discuss whether the signals of changes of ERPs are useful for FES control or not.

## STATE OF THE ART

Event related potentials (ERPs) are special potentials measured from electroencephalograms (EEGs) and caused by special events like watching some pictures, listening to some sounds, or feeling some pain, etc. ERPs are one of very objective signals obtained from human beings when they are working. Farther, since the brains of human beings control their recognitions, judgments and activities and EEGs or ERPs explain directly the states of brains, EEGs or ERPs are one of the most excellent indicators that show the dynamic states of brains. If it is possible to use these potentials for functional electrical stimulation (FES), it becomes very useful by the reason of their characters.

The goal of this report is to consider the usability of ERPs for FES. And our approaches to the goal is to use the character of changes of actual ERPs when subjects are doing some task, to make a model to cause the same changes of ERPs, to do several simulations on the model, to clarify the characters of ERPs estimated by the results of simulation, and finally to discuss the usability for FES.

## MATERIALS AND METHODS

### 1. The Experiments that obtained the changes of ERPs

The experiment is followings;

- (1) The displayed obscure pictures: five kinds of different facial outlines of human being called "1", "2", "3", "4", and "5" in Fig.1. "1" is the most normal, "5" is the most abnormal, and "2", "3" and "4" are among them. The picture "3" is the most obscure one in these pictures. We call these pictures stimuli because they cause several ERPs on a brain.
- (2) The frequency of displaying: 1 time 4 seconds.
- (3) The displaying length of time: for 2 seconds.
- (4) The number of displayed pictures : more than 250 times in total. The five kinds of stimuli are at least included in 50 times each.
- (5) The order of five kinds of pictures: at random.
- (6) The task: the subjects input the key "1" when they think the displayed picture is normal, and the key "2" when they think the picture is abnormal from the viewpoint of engaging.
- (7) EEGs: single polar 19 channels by the 10-20 international method.
- (8) The sampling frequency from analogue EEGs to digital one: 1KHz.

The number of subjects is eight. They are normal male students and an expert of teeth correction. The subjects without the expert are all 21-22 years old.

The analytical methods are followings;

- (1) The measured EEGs were filtered by a kind of adaptive filtering methods[1].
- (2) The filtered data were smoothed by a moving average method and obtaining single recording ERPs.
- (3) Three kinds of event related potentials called P<sub>100</sub>, N<sub>200</sub>, and P<sub>300</sub> were detected automatically from the single stimulated ERPs which are calculated in (2), and getting the latencies and amplitudes of these potentials.
- (4) The regressive lines were calculated for each potential and for the case of each picture.

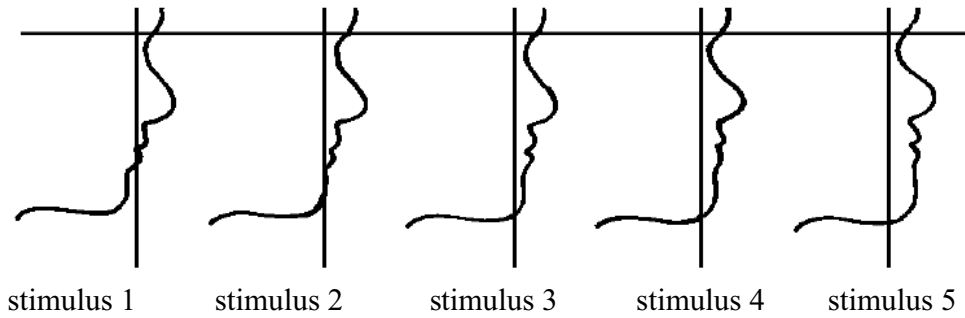


Fig.1 The obscure pictures used for the experiments

### 2. The changes of ERPs

Fig.2 is an example of the filtered data of measured EEGs<sup>3,4,5,7,8</sup>. The bottom of the waves is the first ERP and next is the second one. The potentials of P<sub>100</sub>, N<sub>200</sub> and P<sub>300</sub> appear clearly in the figure (The positive and negative direction is inverse by course of EEG recording.) We detected automatically the latencies of single recorded ERPs like waves in Fig.2, and calculated the regressive line of the latencies<sup>7</sup>. Fig.3 is an example of the regressive lines of N<sub>200</sub>. The regressive line of stimulus“3” is very different from others. The stimulus “3” in Fig.1 is the most obscure to judge abnormal. That is, the change of latencies is the smallest in the most obscure stimulus.

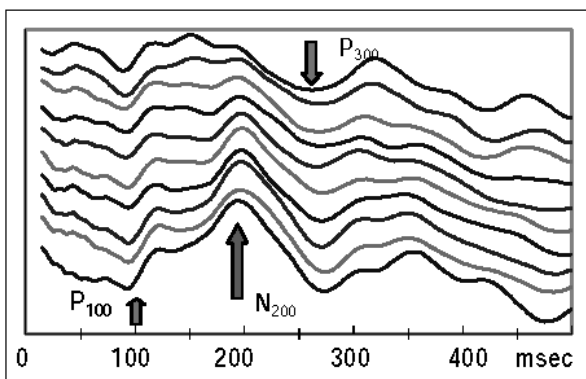


Fig.2 An example of single recorded ERPs

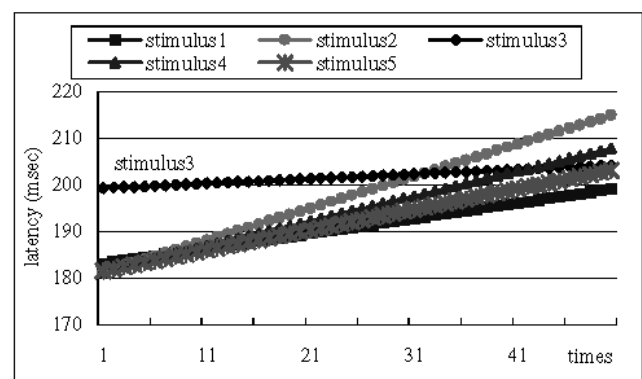


Fig.3 An example of regressive line of N<sub>200</sub>

### 3. A model to explain the changes of ERPs

EEG is the potential measured on the scalp and the potential consists of the sum of bursting neurons. Therefore, when high amplitude is observed, it means that a lot of neurons burst together in a short time. On the other hand, when low amplitude is observed, it means that a little number of neurons burst or the time lag of bursting is relatively large. This phenomenon matches the next formula<sup>8</sup>;

$$ERP_j(t) = \sum_{i=1}^{n(t)} T_i(j) w_i(j) E_i \quad t=1,2, \dots, 500 \text{ msec}, \quad j=1,2, \dots, 250 \text{ times}, \quad w_i(j) = 1, 0 \dots \dots (1)$$

$$1 \leq T(j) \leq 500$$

$Ti(j)$  is the position which the  $i$ -th neuron bursts.  $wi(j)$  is the function which determines the  $i$ -th neuron bursts or not.  $Ei$  is the potential of the  $i$ -th neuron. On this model, we are able to explain that degree of obscurity to some subject determined the value of the function  $wi(j)$ ,  $Ti(j)$  and  $n(t)$ . The most obscure picture causes neurons bursting in a short period.

### 3. Methods of simulations

We determined the parameters on the model (1) are followings;

$$\begin{aligned}
 Ei &= \sin(2\pi/10*k) & k=1, 2, \dots, 10, \pi=3.141592, \\
 n(t) &= (\text{int}) (\sin(2\pi/500*t - \pi/2)*50+51) & t=1,2,\dots,500, \\
 Ti(j)*wi(j) &= (\text{int}) 50*\sin(2\pi/200*k + dd(j)) & k=1,2,\dots,500, -2\pi/100 \leq dd(j) \leq 2\pi/100
 \end{aligned}$$

Fig.4 shows the parameters for the simulation for stimuli without stimulus “3”, and Fig.5 is the parameters for stimulus “3”.  $n(t)$  is the same in these figures, and  $Ti(j)wi(j)$  is slightly different each other. We did some simulations using these values.

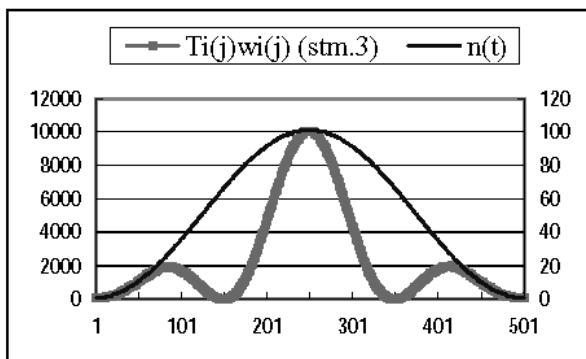


Fig.4 An example of parameters for the simulations in the case of stimulus “3”

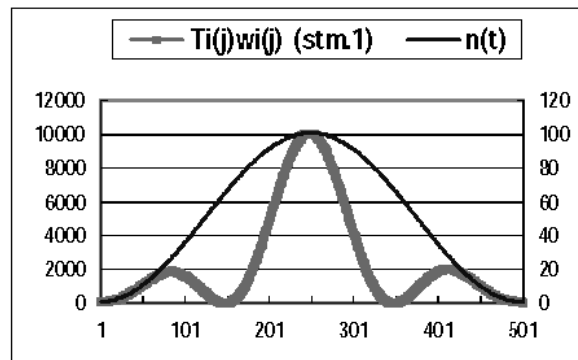


Fig.5 An example of parameters for simulations in the cases of others stimuli

## RESULTS

Fig.6 and 7 are the results of simulations. Fig. 6 is a simulation for stimulus “3”, and Fig.7 is a simulation for other stimuli. Each curve in these figures have peaks 100, 200 and 300msec, and they are very resembled the actual ERPs.  $Ei$  is too small to be recognized in the summed up data. These results of the simulations show that the model (1) can explain the changes of latencies of the actual ERPs.

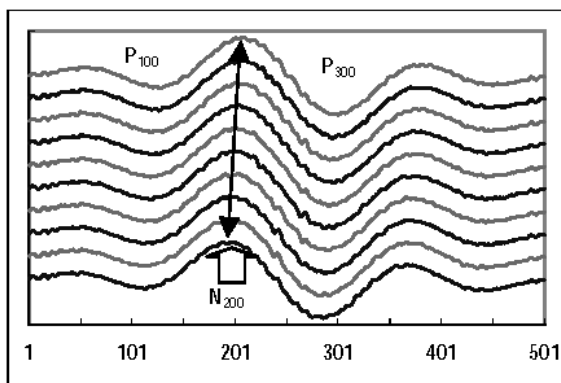


Fig.6 An example of data simulating the stimulus “3”

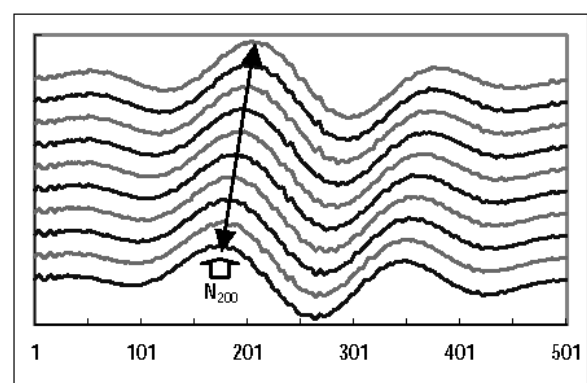


Fig.7 An example of data simulating other stimuli

## DISCUSSIONS

Parameter  $Ti(j)wi(j)$  in Fig.4 and Fig.5 seems almost all the same, however, they are slightly different. Fig.8 shows the difference, and the maximum value of the difference is about 300. The value 300 is not small, but the ratio to the maximum value of  $Ti(j)wi(j)$  is only 3%. This result of simulation shows that

slight change of values of parameters, which can not be recognized by eyes, cause large changes that are observed by eyes.

Fig.9 shows the changes of latencies of  $N_{200}$  in the simulations, and two lines are similar to the stimulus “3” and “others”. These results of simulations suggest that relatively large changes in ERPs or EEGs appear when the small changes occur in a brain. The signal for FES requires objectivity and sensitivity to detect small change of state. Special EEGs like ERPs have these required properties for FES. Therefore it is possible to use the changes of ERPs as a signal to useful FES.

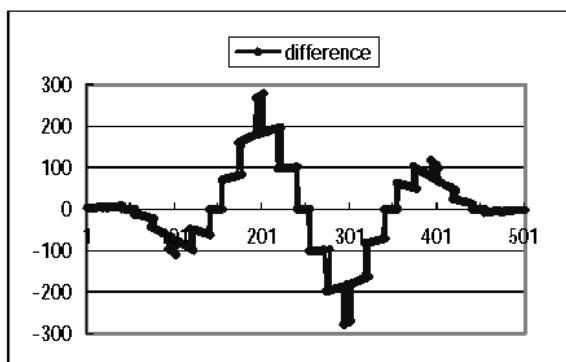


Fig.8 The difference of  $T_i(j)w_i(j)$  in Fig.4 and 5; the difference of parameters between stm1 and stim3 in the simulations

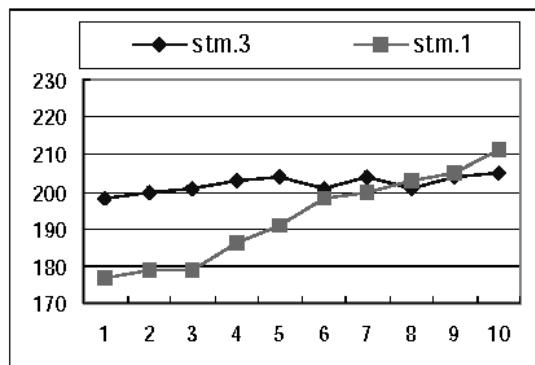


Fig.9 The change of latencies of data simulating stimulus “3” and “others”

#### REFERENCES

- 1 Defayolle, M., et al. Averaged evoked potential in relation to attitude, mental load and intelligence, Measurement of man at work, 1971: 141-152.
- 2 Donchin, E. et al. Application of brain event related potentials to problems in engineering psychology. Psychophysiology, 1986: 702-718.
- 3 Mariko Fujikake, Satoki P. Ninomija, Hideki Fujita. A Coded Summation Method to Measure Evoked Responses of Human Beings, Journal of Medical Systems, 1989, 5(5): 275-292.
- 4 Mariko Fujikake, Satoki P. Ninomija, Hideki Fujita. On Considerations of Coded Summation Method to measure a Slow Vertex Response, Proceedings of the 11th Annual Conference of the IEEE Engineering in Medical and Biology Society, 1989.
- 5 Satoki P. Ninomija, Mariko Fujikake..A Coded Summation Method for Measuring a Visual Evoked Response, Proceedings of 11th Annual Conference of the IEEE Engineering in Medical and Biology Society, 1989.
- 6 M. Fujikake Funada, and Satoki P. Ninomija; Analysis of brain Activity for HCI, Symbiosis of Human and Artifact, 20B, 1995: 839-844.
- 7 Mariko F. Funada, Satoki P. Ninomija, et al. Difference between Changes of single stimulated Experts' ERPs and Those of Non-experts ERPs, Proceedings of the 1998 International Symposium on Noise Reduction for Imaging and Communication Systems, 1998: 91-95.
- 8 Mariko F. Fnada, Satoki P. Ninomija, et.al. Objective Evaluation of Human Fatigue under Computer Works through Event Related Potentials, APIEMS-2000, 42-46, 2000.
- 9 Wickens, C.D. Applications of event related potential research to problems in human factors. Basic issues and applications, 1990: 301-309 .
- 10 Williams, R. Westerkamp, J.J. Single Epoch Adaptive Filtering of Evoked Responses without using A Saparate training Signal. Proceeding of IEEE 1994 (15): 434-435.

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