Prediction of the Input Accuracy of the Hiragana BCI

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Abstract. In this study, we provide an index of classification for BCI-processing. We named the index a discrimination rate. A discrimination rate is the percentage of the LDA classifier, which was able to accurately determine P300. Based on the experimental results, we found that the correct answer rate is changed in proportion to the discrimination rate. Particularly, there was a statistical significance in less than 75% and more than 80% ($p<0.01$). In addition, the correct answer rate also increases with expression of P300.

Keywords: Index of Classification, LDA, P300.

1 Introduction

We have been studying the BCI system based on requirements for ALS patients in the past [1, 2]. In the case of our brainwave measurement with the BCI, training data with the BCI is measured at first, then training with linear discrimination analysis (LDA) is applied as offline processing, and an online experiment is conducted by using a discriminator adjusted with LDA. The weakness of this method is that adjustment of the discriminator might be unsatisfactory depending on the training data. For this reason, averaging was applied to the training data to confirm expression of P300 in the past. However, the shape of P300 has individual differences and confirming P300 only is not sufficient as analysis of training data, leading to possible hindrance in precision of online experiments. In this study, therefore, a hit rate for discrimination of training data ("discrimination rate") is introduced as a new index in offline processing in order to clearly determine whether or not adjustment of a discriminator with LDA is sufficient for online experiments, to conduct evaluation and experiments.

2 BCI System

2.1 Hiragana BCI

The principle of BCI's operation is indicated in Figure 1. Letters arranged in a 6x10 matrix are presented in the display, a row and column randomly flickers as visual stimuli, and brainwaves are recorded for each column and row in synchronization. When the flickering of the matrix is repeated several times, the averaged waveform of

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the brainwave corresponding to each stimulus is recorded in the memory within the computer. Since the P300 component induced with attention to specific letters is observed in this waveform, the row and column with strong response is detected and the intersecting letter can be assumed as the letter to which the subject was paying attention.

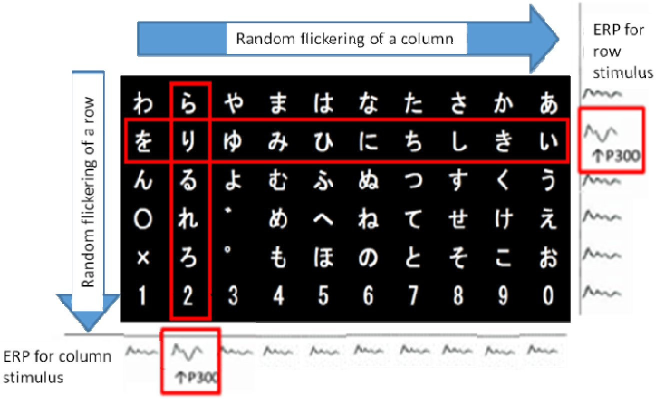

Fig. 1. Principle of BCI's operation (6x10 letter board)

2.2 LDA Processing Method

Since the level of attention has an influence on P300, individual differences occur in amplitude and latency. It is therefore necessary to measure the amount of characteristics by subject and adjust the discriminator to make it suitable for the subject. Training data was measured in advance in this study and the discriminator is adjusted for each subject by using LDA. LDA is one of discriminant analyses and is an analysis method to obtain a linear function that can best discriminate between two groups. The general formula is expressed in the Formula 1. X_i, a_i and a_0 represents a dependent variable, independent variable, regression coefficient, and constant term, respectively. In the case of BCI, the independent variable represents training data and the dependent variable represents discriminant scores. The regression coefficient and constant term are obtained by applying LDA to training data. This regression coefficient and constant term become the amount of characteristics, with the linear discriminant function as the discriminator.

$$Z=a_1X_1+a_2X_2+\cdots+a_nX_n+a_0 \quad (1)$$

The amount of characteristics in a BCI is obtained as follows. First, the sampling frequency of training data goes through the process of downsampling from 256Hz to 64Hz, followed by a band-pass filter between 0.1Hz and 60Hz. Next, data that respond to each stimulus is extracted from the filtered data. Data is extracted at the data length of 100ms before stimulus and 700ms after stimulus, i.e., the total data length of 800ms, and is comprised of 45 potential data in the 800ms length. Once data is extracted, a moving average is conducted on each data, followed by downsampling. The 45 potential data in 800ms are thinned out to 15 with downsampling. After downsampling, a data vector is created for LDA. This data vector becomes the actual independent variable. A discriminator of LDA is created in accordance with the data vector. The discriminator becomes a 121-dimensional linear discriminant function consisting of 120 regression coefficients and one constant term, totaling 121 parameters. Online analysis is conducted by using the discriminator created. This discriminator is established, so that the threshold for the dependent variable Z is divided into 1 or -1 as a discriminant criterion. If the discriminant score of measured data is one or more, it is determined that there is sufficient P300 response; and if it is -1 or less, it is determined that there is no P300 response at all.

2.3 Analysis of Training Data

Figure 2 is a flow chart of the experiment. A traditional BCI experiment had a flow of offline processing including training data measurement, LDA processing and confirmation of P300 components, followed by online processing. In the case of P300 Speller, accuracy in communication improves by conducting BCI training that matches the individual. However, poor training data causes less precision of LDA-adjusted discriminator, leading to an increase in false positives. Low precision of a discriminator causes problems for online experiments, and it is not possible to conduct valid BCI evaluation. It is therefore necessary to confirm precision of training prior to online experiments to determine whether or not sufficient training is conducted. If the training results were poor, training can be repeated to achieve sufficient precision of the discriminator to move onto online experiments. However, precision of training had been confirmed only with ERP analysis in the past. ERP analysis is a method to plot the waveform after the process of averaging to measured data and to count the number of P300 expressions with visual confirmation. The criterion for judging P300 expression is approximately 5μV of positive reaction at approximately 300ms latency. In other words, training is confirmed with ERP confirmation, while precision of the discriminator is not confirmed. In this study, therefore, a hit rate for discrimination of training data (discrimination rate) is introduced as a new index to confirm precision of the discriminator. The discrimination rate [%] in this study means precision of data discrimination with the LDA-adjusted discriminator. Accurate discrimination means that discriminant scores are positive values at the time of target stimuli and negative values at the time of non-target stimuli. Positive discriminant scores less than one are also considered as successful discrimination at this time. Negative discriminant scores are treated in the same manner. The discrimination rate is obtained in accordance with the proportion of the counts of accurate discrimination in all stimuli.

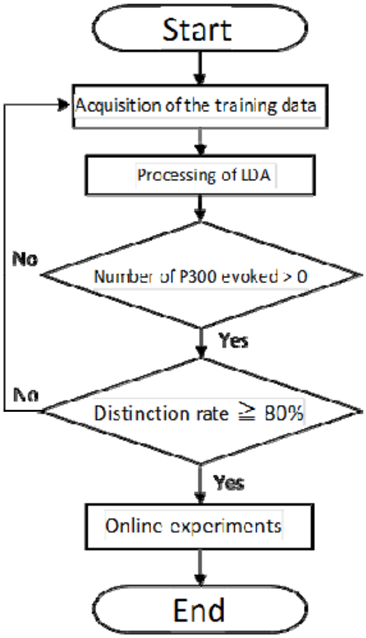

Fig. 2. Flow chart for BCI experiment proposed in this study offline processing includes data measurement up to branching

3 Experiment

3.1 Evaluation Method

The discrimination rate is evaluated by using the value of discrimination rate [%], presence of P300 component, and average correct answer rate [%] in online experiments. The correct answer rate is determined with the number of letters in the letter string detected against the input letter string intended. In the case that intention to mean "o-na-ka-ga-i-ta-i" is detected with "o-na-ka-ga-u-ta-i," for example, the correct answer rate is 5/6=83.3%. Subjects included a total of ten healthy college students: eight males and two females. All subjects operated the BCI for the first time. Subjects participated in the experiment after receiving full explanation on the operation method of the BCI and then practiced. Electrodes were arranged at eight locations including Fz, Cz, Pz, P3, P4, Oz, PO7 and PO8 according to the international 10-20 system [5]. The reference electrode was A1 at the earlobe and the ground electrode was Fpz. The monopolar lead was adopted as a lead method. Highpass filter, lowpass filter and notch filter were set at 0.6Hz, 30Hz and 50Hz, respectively. The brainwave at each electrode was amplified with a biosignal amplifier (g.USBSamp by g.tec). Amplified brainwaves were recorded, analyzed and processed with g.BCIsys developed by using the numerical analysis software MATLAB by MathWorks. The experiment was conducted in a sitting position at rest. One letter was gazed at out of the letters arranged on the 8x8 matrix presented on the monitor (EIZO FlexScanHD2452) established in front of subjects.

The screen was presented on the monitor by operating a notebook PC (Vostro 1320). After that, tasks for offline processing were conducted. For this task, a total 30 stimuli, i.e., 15 times each for one row and one column, were given for one-letter entry. In regards to stimulus onset asynchrony (SOA), the duration of flashing (Flashtime) and extinction (Darktime) is fixed at the rate of 4:3 by setting the stimulus interval at 140ms. LDA is applied after that, and an online experiment (BCI experiment) is conducted in accordance with the discriminator obtained. For the online experiment, a total of 20 stimuli, i.e., 10 times each for one row and one column, is given for one-letter entry. The stimulus interval is not changed. In this experiment, a six-letter word is entered by using the copy-spelling method where letters to be entered are pre-set as a letter-entry task.

4 Discrimination Rate and Correct Answer Rate

The discrimination rate at this time was less than 80% for all 10 subjects. Therefore, we also obtained a discrimination rate in regards to the data measured in our previous studies. The experimental method was the same as this experiment, while a 5x5 letter board was used in the tasks for offline analysis. An 8x8 letter board was used in regards to tasks for online analysis. Data for five healthy people in their 20s was used including two males and three females. Figure 3 shows the results of discrimination rate and correct answer rate for all subjects. The horizontal axis represents the discrimination rate for training data [%] and the vertical axis represents the correct answer rate for online experiments [%].

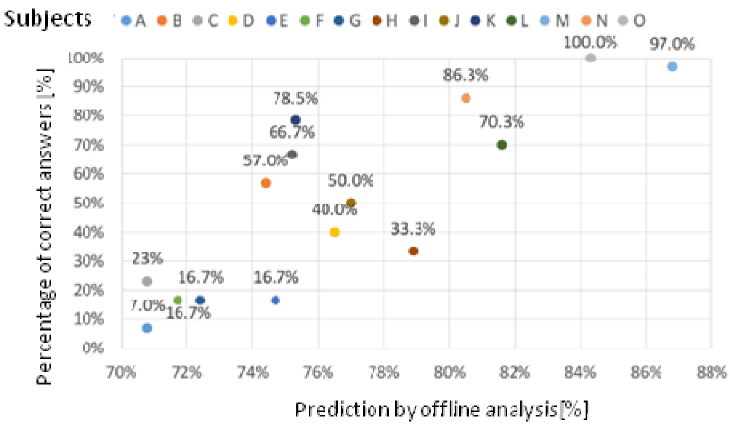

Fig. 3. Scatter diagram of discrimination rate and correct answer rate (for 15 subjects)

When the discrimination rate is compared with the correct answer rate, the discrimination rate tends to be higher if the average correct answer rate is higher, and vice versa. In other words, we can assume that the discrimination rate bears a proportional relationship to the correct answer rate. When the data on subjects are divided into three sections including less than 75%, between 75% and 80%, and 80%

or more, the average correct answer rate was 22.8±3.1[%], 53.7±3.5[%], and 88.4±1.8[%] in the case of less than 75%, between 75% and 80%, and 80% or more, respectively. A significant difference was recognized as a result of one-tailed t-test in regards to the average correct answer rate for less than 75% as well as 80% or more ($p<0.01$). A significant difference was also recognized between 75% an 80% as well as 80% or more ($p<0.01$). 70% to 80% accuracy in communication with a BCI tends to be considered as passing scores. In consideration of the results on the discrimination rate and correct answer rate at this time, 80% or more of a discrimination rate for training data is considered as one indication for offline processing.

5 Summary

A discrimination rate was introduced as a new index to discriminate a target for online processing of BCI in this study to conduct evaluation and experiments. As a result, a significant difference was successfully confirmed when a t-test was conducted in regards to the average correct answer rate in two sections of discrimination rate: less than 75% and 80% or more ($p<0.01$). A significant difference was also confirmed in two sections: between 75% and 80% as well as 80% or more ($p<0.01$). Based on this above, a higher discrimination rate is considered to be relating to a higher correct answer rate in online processing. It was also found that the correct answer rate is higher if P300 expression can be confirmed at the same time. However, it seems important to achieve a higher discrimination rate in order to further improve the correct answer rate. Therefore, precision of online processing can be successfully maintained by confirming the discrimination rate with the use of BCI in the future. We plan to further review the influence on the discrimination rate depending on the size of a letter board used as well as duration of training.

References

1. Inada, H., Tanaka, H.: Need Survey for and Development of Pictogram-Scanning Method for a BCI. In: Proceedings of HI Symposium, pp. 179–182 (2011)
2. Kawano, R., Ito, M., Tanaka, H., Otera, A., Zenba, Y., Takahashi-Narita, K., Fukuda, M., Asai, N.: Hiragana Entry-Type BCI and Application to ALS Patients. In: Proceedings of the 8th Spring Conference of Japan Society of Kansei Engineering, pp. 8–12 (2013)
3. Nittono, H., Hori, T.: Use of Event-Related Potentials in Psychological Research, Hiroshima University, Faculty of Integrated Arts and Sciences, Bulletin Science Edition 26, 15-32 (2000)
4. Farwell, L.A., Donchin, E.: Talking off the Top of Your Head: Toward a Mental Prosthesis Utilizing Event-Related Brain Potentials, Electroen-ceph. Clin. Neurophysiol. 70, 510–523 (1988)
5. Jasper, H.H.: The Ten-Twenty Electrode System of the International Federation. The International Federation of Society for Electroencephalography. Recommendation for the Practice of Clinical Neurophysiology. p.8