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A Study of Evaluation Method on Image Recall Capacity using EEG

Ssang-Hee Seo
Department of Computer Science and Engineering, 7 Kyungnamdaehak-ro, Masanhappo-gu, Changwon-si, 51767 Gyeongsangnam-do, Republic of Korea

Abstract: The purpose of this study is to evaluate individual recall capacity. To this end, recall capacity of individual was evaluated to the changes of EEG when they recall about that images after watching the images. The 27 healthy college students (male 16, female 11) were selected. Before participating in the experiment, they prepared a consent form. Their brain waves were subsequently measured. The subjects all consisted of persons who were right-handed and without brain-related diseases. EEG data measured at the occipital and frontal lobe. Beta (13~30 Hz) band and theta (4~8 Hz) band were abstracted through analyzing the relative power spectrum. Classification was made between the individuals who are good and not good at recalling images. The result showed that the relative beta power of the occipital lobe was low when they recall the images compared to watch the images. This result showed similar results in the relative theta power in the frontal lobe. However, quiz score and variation in beta power at the occipital lobe indicates a high correlation. It means that the higher the quiz score, the greater the change of relative beta power in recall state. But the variation of theta power at the frontal lobe did not produce significant results. We divided into three groups to identify recall capacity of individual based on discriminating factors. We calculated the mean value of difference between beta power in stable state and beta power in recall state. The highest group of mean value of difference showed the highest quiz score at the occipital lobe. The difference between the three groups was very large. These results showed that those who have a high recall capacity show high beta power difference in recall state at the occipital lobe. This suggests that recall capacity has connection to a beta power variation at the occipital lobe and that there exists an individual difference in recall capacity. Beta power at the occipital lobe can be used as an indicator of individual recall capacity.

Key words: Image recall, EEG, working memory, memory task individual difference, capacity, significant

INTRODUCTION

We receive lots of information through eyes in our daily lives. The information received is stored in our brain through various pathways. When we try to recall a scene we've seen before, we recall the information stored in each area of our brain in a lump. When we try to recall something, it may a something before or after a long period of time. Working memory is the system which holds transitory information and processes which allows this information to be manipulated. It holds controllers which allow integration, disposal and retrieval of short-term memory information. Short-term memory is the information that is stored in mind within few seconds to approximately 30 sec. Short-term memory capacity varies from person to person. Short-term memory is a part of working memory. Specially, the capacity of short-term memory serve as a criterion for assessing the cognitive ability of individuals. Many studies report that cognitive disorder patients occur in impairments of short-term memory (AI-Qazzaz *et al*., 2014). Memory and recall are closely related. Those who remember better tend to be apt to recall things. Therefore, this study was intended to evaluate recall capacity of individual based on EEG and to grasp the individual difference through it. There are many research reports on the changes within the brain when recalling images. From the mid-1980's, researches carried on with regard to the areas of cerebral response while in mental imagery. Roland tried to explain the regional changes of bloodstream through Single Photon Emission Computed Tomography (SPECT) while the participants in the experiment were imagining of strolling with their friendly neighbors (Roland and Friberg, 1985). As the result, responses were shown at parietal and temporal lobes and no definite change was found at the occipital lobe. But then, Goldberg *et al.* (1987) looked into the blood flow while mental imagery is being made, using SPECT. It is for example, the experiment in the form of remembering words using association signs. It can also include a question that calls for a difficult answer to make, such as "Which is the darker green, grass or a pine tree?" The result obtained through such an experiment is that

visual imagery is related to the activity of occipital lobe and temporal lobes. Charlot *et al.* (1992) collected information using SPECT while their subjects were recalling images under the paradigm of image-scanning test developed by Kosslyn *et al.* (1993) and Charlot *et al.* (1992). Also, they found out that visual cortex is subject to activity. There are many other research results and most of them report that when visualizing an image, it is activated at the occipital lobe (Farah *et al.*, 1989; Goldenberg *et al.*, 1991; Kosslyn *et al.*, 1993; Tippett *et al.*, 1992). And there exist a lot of reports on theta band activity during working memory task as to temporary memory in addition to visual mental imagery (Jensen and Tesche, 2002; Burgess and Gruzelier, 1997; Doppelmayr *et al.*, 1998; Kahana *et al.*, 1999; Klimesch, 1999; Tesche and Karhu, 2000; Raqhavachari *et al.*, 2001; Araujo *et al.*, 2002). Based on these research results, our hypothesis has been established that in case of those who are good at recalling images, beta band will be activated at the occipital lobe while carrying out this job and theta band will be activated at the frontal lobe while looking at an image.

MATERIALS AND METHODS

Subjects: The 27 healthy college students in their twenties (male 16, female 11) were selected and after their agreement to the experiment, their brain waves were measured. The subjects all consisted of persons who were right-handed and without brain-related diseases.

Measurement: Brain wave was measured by QEEG-4 (LAXTHA) and 256 Hz was selected for a sampling frequency. The position of electrodes went by the international 10-20 electrode arrangement, using the channels of FP_1, FP_2 (cognitive area) and O1, O2 (visual area). And standard electrodes were applied to Cz. Electrode arrangement plan is shown in Fig. 1.

Experiment paradigm: For the first one-minute stable state taken with their eyes closed, the subjects were presented with a particular image with a direction to look carefully for the next one minute. Then, still for one more minute, the job of recalling the image they looked at was carried out with their eyes closed. After that, they were told to solve ten items of quiz about the image which asked the distinctive features of the image. They are objective questions such as "What color is the flag hanging on the building"? "How many people are shown in the image?" Figure 2 shows the process of carrying on the experiment.

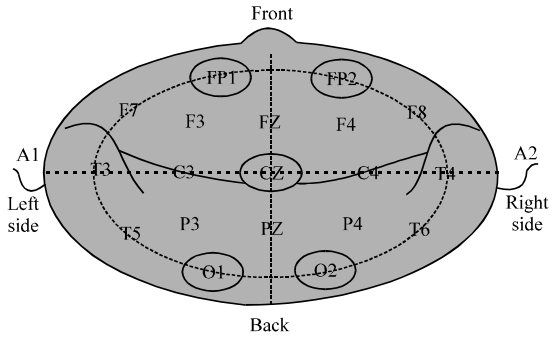

Fig. 1: Electrode arrangement

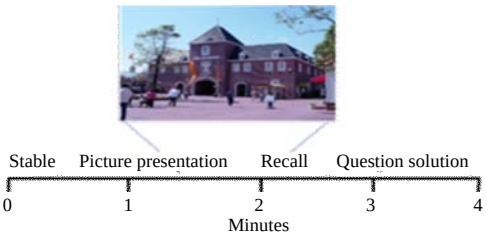

Fig. 2: Procedure of experiment

Processing of the EEG signal: Frequency of 4~30 Hz was selected to remove the noise from raw data and the values of RPS (relative power spectrum) were found in the frequency band of brain waves, theta (4~8 Hz) and beta (13~30 Hz), using FFT (Fast Fourier Transform).

Statistical analysis: SPSS 12.0 was used for statistical analysis and all the results were considered significant on the significance level of $p<0.05$. Pearson's correlation analysis was performed to see if there is relation between derived beta variation at the occipital lobe and theta variation at the frontal lobe which was to be used for factors in statistical analysis and quiz scores, K-mean collective analysis was done on EEG factors to understand whether there exists individual differences with a result of division into three groups and Kruskal-Wallis analysis was performed to judge whether the difference in ranking between groups is significant or not.

RESULTS AND DISCUSSION

Results of EEG activity: Figure 3 and 4 show distinctive quality in brain waves for one person in his reposing with shut eyes, looking at an image with open eyes and imagining of the image with shut eyes. Most of participants show the pattern like this. It is found that beta power at the occipital lobe and theta power at the frontal lobe are the greatest in presenting an image while

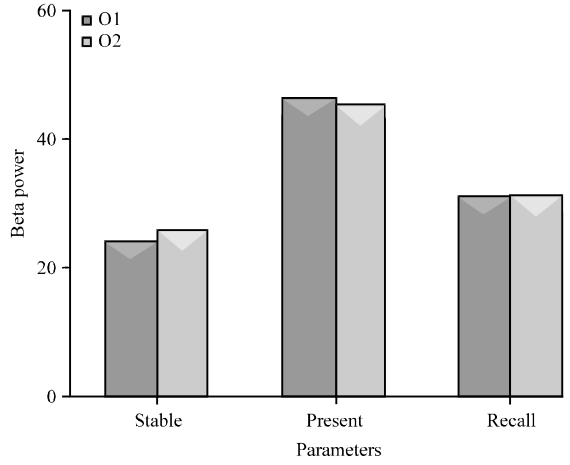

Fig. 3: RPS analytic values of each task in beta wave

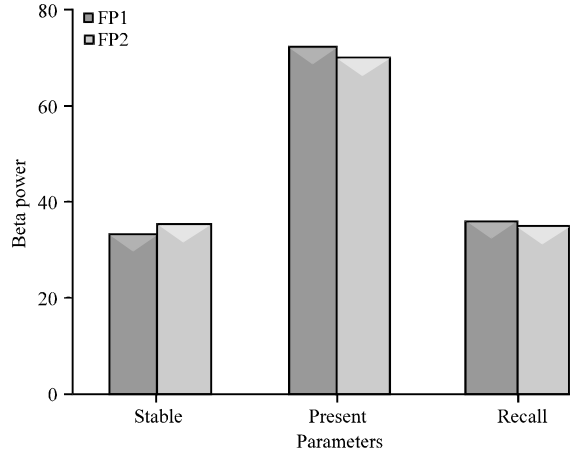

Fig. 4: RPS analytic values of each task in theta wave

the lowest in stable state. To evaluate personal recall capacity, this research noted from the measured EEG data the change in beta band (8~13 Hz) at the occipital lobe and theta band (4~8 Hz) at the frontal lobe through the analysis of power spectrum.

We assumed that when recalling an image, beta activity at the occipital lobe will be greater in persons who are good at recalling images than in those who are not good. Also in relation to the movement of working memory, we assumed that for persons who are good at thinking images, theta activity is activated both when looking at an image and when recalling it with a relatively less difference. Therefore, we established two discriminating factors. The first discriminating factor is a difference between beta power when they recall and beta power when they are in stable state. The second factor is a difference between theta power when they see images and theta power when they recall the images. We made

Table 1: Correlation between quiz scores and discriminating factor values

Measured region	Discriminating element	Significance probability (p)	Correlation coefficient
O1	Discriminating factor 1	0.004	0.539
O2	Discriminating factor 1	0.028	0.422
FP1	Discriminating factor 2	0.581	0.111
FP2	Discriminating factor 2	0.445	0.153

Table 2: Sorting test by groups according to discriminating factors

Measured region	Discriminating element	Significance probability (p)	F-test value
O1	Discriminating factor 1	0.000	29.546
O2	Discriminating factor 1	0.000	154.812
FP1	Discriminating factor 2	0.000	25.606
sFP2	Discriminating factor 2	0.000	56.820

two hypotheses that those who are good at recalling images will have a larger value of the first factor compared to those who are not. Also, those who are good at recalling images will have a smaller value of the second factor, compared to those who are not. The first factor indicates the difference in beta power when in stable state in each image recall from the position of occipital lobe O1 and O2. The second factor indicates the difference in theta power when looking at and recalling an image from the position of frontal lobe FP1 and FP2. The first factor is referred to as discriminating factor1 and the second factor is discriminating factor 2.

Results of statistical analysis: To investigate the relationship between EEG activity at occipital and frontal lobe and recall capacity, correlation was analyzed between discriminating factors 1 and 2 and quiz scores regarding images.

Generally, data can be considered significant when $p<0.05$. Table 1 which indicates significance probability for each region, data was estimated to be significant at the occipital lobe with this standard satisfied but they turned out to be insignificant at the frontal lobe. This means that those with higher beta activity in recalling an image at the occipital lobe, compared to stable state are people who are good at recalling images. Also, to look into the individual difference in recall capacity, K-mean collective analysis was performed on discriminating factor 1 and 2 to sort them into three groups. Significance by groups was analyzed through F test and Kruskal-Wallis test.

From Table 2 and 3, it is shown that classification of three groups has been made on EEG discriminating factors and that there is a significant difference in EEG discriminating factors between the three groups. Table 4 indicates mean values on discriminating factor 1 and 2 for each group. This means there is a significant difference shown between groups between beta activity at the occipital lobe and theta activity at the frontal lobe and

Table 3: Significance test by groups according to discriminating factors

Measured region	Discriminating element	Significance probability (p)	Chi square
O1	Discriminating factor 1	0.000	16.757
O2	Discriminating factor 1	0.000	16.879
FP1	Discriminating factor 2	0.000	18.043
FP2	Discriminating factor 2	0.000	20.571

Table 4: Mean value of discriminating factor 1 by groups

Group	O1	O2	Quiz score
Class 1	10.16	9.04	6.25
Class 2	1.77	2.09	4
Class 3	-2.95	-2.63	3.1

that especially the group with high beta activity at the occipital lobe is high in quiz score, possessing the highest recall capacity.

CONCLUSION

In this study, we measured EEG of the subject of college students to evaluate recalling capacity on images by power spectrum analysis. We proposed the factors to evaluate individual capacity using beta and theta activity from the occipital and frontal lobe which were proved through statistical methods. As a result of analysis individual recall capacity can be assessed using the difference of beta activity between recall state and stable state at the occipital lobe and it was divided the persons who are good at recalling and who are not, using the discriminating factors proposed in this study. There exist many researches on image recalling capacity of individual. These studies are mostly concerning specific positions on the cerebrum or activity of particular frequency band. However, researches are rarely found that identify individual difference by evaluating EEG signals. The results of this research present a standard index that can evaluate recalling power of individual. Based on this research result, we are planning on the research with a view to materializing a system that can evaluate personal imagining power.

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