World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:8, No:8, 2014

Determination of the Concentrated State Using Multiple EEG Channels

Tae Jin Choi, Jong Ok Kim, Sang Min Jin, Gilwon Yoon

***Abstract*—**Analysis of EEG brainwave provides information on mental or emotional states. One of the particular states that can have various applications in human machine interface (HMI) is concentration. 8-channel EEG signals were measured and analyzed. The concentration index was compared during resting and concentrating periods. Among eight channels, locations the frontal lobe (F_{p1} and F_{p2}) showed a clear increase of the concentration index during concentration regardless of subjects. The rest six channels produced conflicting observations depending on subjects. At this time, it is not clear whether individual difference or how to concentrate made these results for the rest six channels. Nevertheless, it is expected that F_{p1} and F_{p2} are promising locations for extracting control signal for HMI applications.

***Keywords*—**Concentration, EEG, human machine interface.

I. Introduction

NOWADAYS rapid development of technologies especially information technology brings various social interests. People are constantly occupied with the internet, smartphone, SNS and wireless networks that cover almost all the corners in the world. Rising are renewing interests on interfacing or controlling devices or machines around us by thought. There are apparent advantages of interfacing devices by the thought such as an upgrade of information technology. More importantly, it is worthy for researches if the convenience that handicapped individuals can have is taken into account.

Brainwave or EEG has been one of the most useful signals for human machine interface (HMI). There have been numerous researches on this subject. One of promising control signals based on EEG analysis is generated by intentional concentration. There have been studies on measuring whether one's EEG are changed by concentrated state and on how thought concentration can be implemented for controlling or interfacing devices [1]-[5].

In order to use EEG control signal for practical cases, the number of channels should be minimized when volume and handiness should be considered. Kang and Yoon proposed a use of single channel EEG measurement to provide control signal [4]. Even though single channel devices would be useful, they did not discuss about which particular single channel should be selected. In this study, multiple EEG channels were examined so that which channels might produce significant changes of EEG signal during concentration.

T. J. Choi is at the Department of Electronics, Seoul National University of Science and Technology, Seoul, Korea. J. O. Kim and S. M. Jin are also with the Department of Electronics, Seoul National University of Science and Technology. Correspondence to G. Yoon. G. Yoon is with Department of Electronic & IT Media Engineering, Seoul National University of Science and Technology, Seoul, Korea (phone: 82-2-970-6419; fax: 82-2-979-7903; e-mail: gyoon@seoultech.ac.kr).

II. Methods

It has been widely known that frequency bands of EEG correspond to certain brain activities. Table I summarizes EEG frequency ranges and their associated brain activities [5]. Previous researches on concentration report that alpha and beta bands are related with mental activities such as attention, focus or concentration.

TABLE I
Brainwave Frequency Bands versus Brain Activities

Band	Frequency [Hz]	Activities
Delta, δ	0.1 ~ 3	Deep sleep, awaken, attention
Theta, θ	4 ~ 7	Drowsiness, idling
Alpha, α	8 ~ 12	Relaxed
SMR	12 ~ 15	Concentration without movement
Beta, β	15 ~ 20	Active thinking, focus
High beta	20 ~ 35	Stiff, anxious, stress

SMR denotes sensory motor rhythm

In our investigation, EEG was measured using a commercial device (Laxtha QEEG-8^{TM}). EEG data were acquired at a sampling rate of 512 Hz and raw data were amplified. Fast Four Transform (FFT) was performed every second [6]. Data were bandpass filtered and the absolute power spectrum was calculated at each frequency band following routines as shown in Fig. 1.

Fig. 1 Steps of analyzing EEG data

In general, it has been reported that beta wave increases and theta decreases during concentration. Power ratio between beta and theta bands has been used as a parameter for determining the concentrated state [4], [5]. Following this index, it can be determined whether concentration is reached by checking index values.

For our experiment, eight electrodes were attached at F_{p1}, F_{p2}, T_3, T_4, C_3, C_4, O_1 and O_2 following the International 10-20 system [7], [8]. A_2 was used as reference and the nape, the back of the neck, was set to ground. Electrode positions are illustrated in Fig. 2.

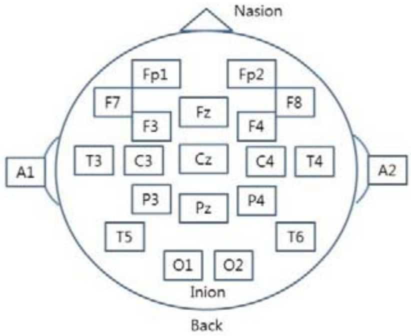

Fig. 2 Electrode positions following the International 10-20 System

A small amount of conductive gel was applied to each electrode and the electrode was placed to each position using gauze. Experimental protocols go as follows. First there was a period of rest for 30 seconds. Then, a subject was guided to a concentration period of 60 seconds. During 30-second rest, each person sat on the chair and waited in comfortable state. The subject did not watch computer monitor at this time. Then the buzzer sounds rang. At this time the subject watched a red spot on the center of computer monitor. At least 5-minutes rest was assigned before the next EEG measurement in order to minimize tiredness or exhaustion from the previous measurement. In this manner the subject was able to concentrate again without the influence of the previous experiment. In analysis, the following index of concentration was used [5], [9].

$$\text{Index} = \text{power of } [\{\beta + \text{SMR}\} / \theta] \quad (1)$$

Fig. 3 shows a typical example of measured concentration indices during concentration experiment. Y-axis indicates the concentration index and x-axis is the time. The red vertical line indicates the mark of 30 seconds that separates resting and concentration periods. Index values were computed at every second.

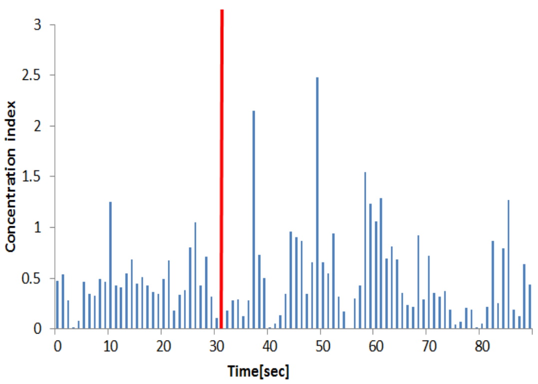

Fig. 3 An example of measured concentration indices with respect to time was for one particular channel. The red vertical line marks 30 seconds when the subject started concentration

In this investigation, we counted the number how many times the index was higher than a threshold value. This number was called as occurrence or occurrence number. The threshold value was set to be 30 percent higher than an averaged index value during the period of resting. As can be seen in Fig. 3, concentration indices does not increase all the time nor decrease throughout a monitoring period. EEG waveform is fluctuating all the time and brain activities are indeed the result of complicated processes. Therefore, this occurrence number was counted over a period of time and was the most important parameter in determining whether concentrated state was reached in this study.

Fig. 4 shows an example of the number of counts, occurrence number, over a period of 30 seconds. X-axis 30 means 30 seconds after our measurement. There was the rest of 30 seconds and therefore 30 seconds (x-axis) indicated the start of concentration. Y-axis value of 7 at 30 seconds was the number of occurrence counted for 30 seconds between 30 and 60 seconds. The red vertical line was at 45 seconds and the number of occurrence was 12. This means that the number was counted between 45 and 75 seconds. 45 seconds was the time when the counted started and counting was continued over a period of 30 seconds. This indicated that the number of counts were highest after 11 ~ 16 seconds after the concentration started. Therefore, throughout our analysis, occurrence counting began 15 seconds after the start of concentration and continued over a period of 30 seconds.

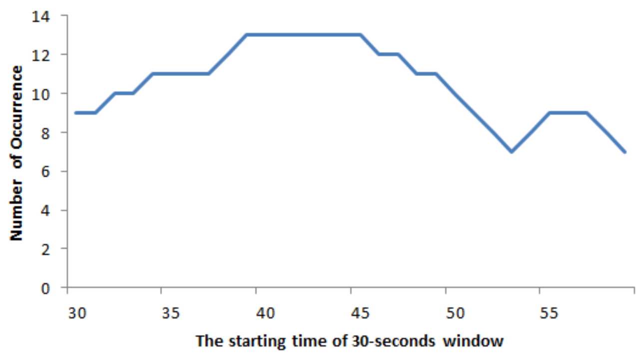

Fig. 4 Number of occurrence over a period of 30 seconds. X-axis indicates the starting time of counting

III. Results

Various brain activities are responsible for EEG signals at different locations in brain. 8 channels were selected so that they might cover clinical meaningful locations. Channels 1 and 2 were attached to the frontal lobe (F_{p1} and F_{p2}). The frontal area is associated with high level information processing. Channels 3 and 6 were T_3 and T_4. These locations are related with auditory nervous system. Channel 4 was at C_3 and channel 5 was placed on C_4. These two channels were located at the border line between the frontal and parietal lobes. Channels 4 and 5, therefore, covered regions of motor and somatesthesia, especially hand movements. Channels 7 and 8 were at O_1 and O_2 respectively [10].

Table II and Fig. 5 illustrate the results for Subject A. Table II is a result summary that shows the averages of 5 measurements. Fig. 5 illustrates comparison between rest and concentration periods in terms of occurrence. Fig. 5 shows definite increases at CH 1 and CH2 during concentration. These channels are related with the activities of the frontal lobe. As concentration can be thought process, experimental results were in accordance with theoretical explanations.

TABLE II
A SUMMARY OF SUBJECT A BETWEEN REST AND CONCENTRATION; AVERAGE OF 5 MEASUREMENTS ARE SHOWN

	Electrode location	Index during rest	Threshold index	Occurrence during rest	Occurrence in 45 – 75 seconds	Ratio between concen and rest
CH1	F_{p1}	0.488	0.635	5	20	4
CH2	F_{p2}	0.577	0.750	5	18	3.6
CH3	T_3	0.521	0.678	3	2	0.667
CH4	C_3	0.463	0.602	5	4	0.8
CH5	C_3	0.414	0.539	5	2	0.4
CH6	T_4	0.633	0.823	5	2	0.4
CH7	O_1	0.868	1.128	4	3	0.75
CH8	O_2	0.859	1.117	5	2	0.4

Index is given as in (1).
Occurrence is the number of indices greater than threshold index.

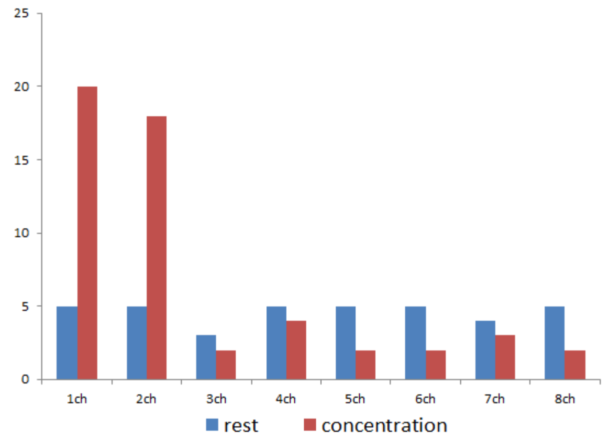

Fig. 5 Comparison of occurrence between rest and concentration periods (Subject A)

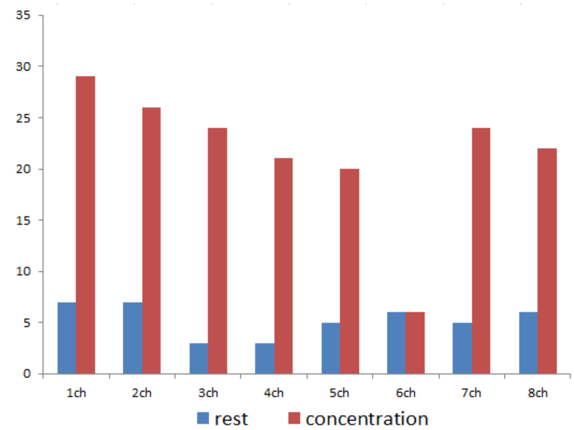

Fig. 6 Comparison of occurrence between rest and concentration periods

Table III and Fig. 6 report the summary of experimental results for Subject B. Subject B reveals another type of trends. Increase in channels 1 and 2 during concentration were the same as shown with Subject A. However, Subject B had the increase of the index for the rest channels. Channel 6 was the only exception.

TABLE III
A SUMMARY OF SUBJECT B BETWEEN REST AND CONCENTRATION; AVERAGE OF 5 MEASUREMENTS ARE SHOWN

	Index during rest	Threshold index	Occurrence during rest	Occurrence between 45 – 75 seconds	Ratio between concentration and rest
CH1	0.329	0.428	7	29	4.142
CH2	0.418	0.544	7	26	3.714
CH3	0.729	0.948	3	24	8
CH4	0.513	0.667	3	21	7
CH5	0.450	0.585	5	20	4
CH6	1.953	2.539	6	6	1
CH7	1.014	1.319	5	24	4.8
CH8	0.824	1.072	6	22	3.66

Index is given as in (1).
Occurrence is the number of indices greater than threshold index.

IV. DISCUSSIONS

There have been a few different ways of analyzing concentrated states. Table IV compares each feature among different algorithms of determining concentration. The method introduced by [5] did not set a threshold for the index and higher index indicated higher level of concentrated state. There

International Science Index, Biomedical and Biological Engineering Vol:8, No:8, 2014 waset.org/Publication/9999102

was no way of determining whether a particular subject was in concentration. In this case it is difficult to extract control signal for HMI applications. Kang and Yoon proposed a threshold level that was 30 percent higher than the averaged index during resting period [4]. Then, it was declared that the concentrated state was reached if the index became higher than the threshold. This method had its own criterion in general. Unfortunately as shown in Fig. 3 indices were not changing smoothly with ups and downs as well as spike noises induced possibly by EOG and other unknown causes. As well known, EEG waveform is that smooth and this algorithm may fail under these conditions.

That was why a window of 30 seconds was introduced in averaging indices so that random noises might be avoided. A waiting period of 15 seconds was also introduced because indices increased gradually after concentration started as shown in Fig. 4.

TABLE IV
COMPARISONS OF DIFFERENT METHODS OF DETECTING CONCENTRATED STATE

	[5]	[4]	Proposed algorithm
Analysis method	monitoring of indices after concentration starts	moment of the index higher than threshold within 60 sec	counting number of indices higher than threshold during 30 sec after the start of concentration
Decision on concentrated state	higher index indicates higher concentrated state	determine when concentrated state is reached	determine whether concentrated state is reached
Threshold level	none	index 30% higher than that of resting period	index 30% higher than that of resting period

CH 1 and CH2 can be promising channels that determine concentration. Values of the index during concentration are much higher than those of resting time. It is interesting to note the differences between subject A and subject B. Subject A watched a red dot on the screen and imagined it as black hole during concentration. On the other hand subject B imagined that he was playing an electronic game within the red spot. Subject B was more immersed in the game. However, it is not clear at this time whether this individual difference on how to concentrate made conflicting results for the rest channels. It is necessary to extend our experiments including more subjects as next step.

ACKNOWLEDGMENT

This study was supported by the Research Program funded by Seoul National University of Science and Technology.

REFERENCES

[1] L. Kirkup, A. Searle, A. Craig, P. Mclsaac, and P. Moses, "EEG-based system for rapid on-off switching without prior learning", *Medical and Biological Engineering and Computing*, vol. 35, pp. 504-509, 1994.

[2] J. R. Wolpaw, D. J. McFarland, "Multichannel EEG-based brain-computer communication," *Electroenceph. clin. Neurophysiol*, vol. 90, pp. 444-449, 1994.

[3] B. Blankertz, F. Losch, M. Krauledat, G. Dornhege, G. Curio, K. R. Muller, "The Berlin Brain-Computer Interface: Accurate Performance From First-Session in BCI-NaÏve Subjects," *Biomedical Engineering*, IEEE Transactions on, Vol. 55, No. 10, pp. 2452-2462, October 2008.

[4] B-K Kang and G. Yoon, "Generation of Control Signal based on Concentration Detection using EEG signal", *Journal of The Institute of Electronics Engineers of Korea*, vol. 50, no. 12, pp. 3193-3196, December 2013.

[5] S-Y Lee and C. Lee "Research on the Game for increasing intensive power using EEG signal", Department of Computer Science, The Graduate School of Industrial information, Woosong University , pp. 7-41, January 2009.

[6] G. Li, and W-Y Chung, "A Pilot Study on the use of Electroencephalography Sensors for Measuring the Eyelid Closure Degree" Department of Electronic Engineering, Pukyong National University Busan, Korea, pp. 2-4,2013.

[7] J-Y Shim and B-J Ko, "Effects of Brain Development Program for Improving Self-regulation and Concentration in Youth", *Korean journal of youth studies*,vol.16, no.9, October 2009.

[8] S. Y. Chung, H. J. Yoon ,"Analysis of Electroencephalogram Electrode Position and Spectral Feature for Emotion Recognition", *Journal of the Society of Korea Industrial and Systems Engineering*, vol. 35, no. 2, pp.64-70, June 2012.

[9] Y. Sung, K. Cho, and K. Um, "A Framework for Processing Brain Waves Used in a Brain-computer Interface", *Journal of Information Processing Systems*, vol.8, no.2, June 2012.

[10] E-Y Lee, "The effects of musical stimulus on EEG spectra of listeners", Major of Clinical Music Therapy, Graduate School of Music Therapy, Sookmyung Women's University, pp. 9-34, December 2004

Tae Jin Choi is a student at the Department of Electronics and IT Media Engineering, Seoul National University of Science and Technology. He has been involved in projects utilizing EEG and other biosignals.

Gilwon Yoon received his B.S. in Electrical Engineering from Seoul National University, Seoul, Korea in 1977. His degrees of M.S. and Ph.D. in Electrical and Computer Engineering were obtained from the University of Texas at Austin, U.S.A. in 1982 and 1988 respectively. He worked as Medical Team Director at Samsung Advanced Institute of Technology, Korea between 1992 and 2003. He is currently professor at Seoul National University of Science and Technology since 2003.