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 (Fp1 and Fp2) 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 Fp1 and Fp2 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 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.

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.

In our investigation, EEG was measured using a commercial device (Laxtha QEEG-8™). EEG data were acquired at a sampling rate of 512 Hz and raw data were amplified. Fast Fourier 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.

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 Fp1, Fp2, T3, T4, C3, C4, O1, O2 following the International 10-20 system [7], [8]. A2 was used as reference and the nape, the back of the neck, was set to ground. Electrode positions are illustrated in Fig. 2.
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].

\[ \text{Index} = \frac{\text{power of } \{ \beta + \text{SMR} \} / \theta}{\theta} \]  

(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.

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.

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 (Fp1 and Fp2). The frontal area is associated with high level information processing. Channels 3 and 6 were T3 and T4. These locations are related with auditory nervous system. Channel 4 was at C3 and channel 5 was placed on C4. 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 O1 and O2 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.
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>
<thead>
<tr>
<th>Electrode location</th>
<th>Index during rest</th>
<th>Threshold index</th>
<th>Occurrence during rest</th>
<th>Occurrence in 45 – 75 seconds</th>
<th>Ratio between concentration and rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1</td>
<td>0.488</td>
<td>0.635</td>
<td>5</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>CH2</td>
<td>0.577</td>
<td>0.750</td>
<td>5</td>
<td>18</td>
<td>3.6</td>
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<tr>
<td>CH3</td>
<td>0.521</td>
<td>0.678</td>
<td>3</td>
<td>2</td>
<td>0.667</td>
</tr>
<tr>
<td>CH4</td>
<td>0.463</td>
<td>0.602</td>
<td>5</td>
<td>4</td>
<td>0.8</td>
</tr>
<tr>
<td>CH5</td>
<td>0.414</td>
<td>0.539</td>
<td>5</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>CH6</td>
<td>0.633</td>
<td>0.823</td>
<td>5</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>CH7</td>
<td>0.868</td>
<td>1.128</td>
<td>4</td>
<td>3</td>
<td>0.75</td>
</tr>
<tr>
<td>CH8</td>
<td>0.859</td>
<td>1.117</td>
<td>5</td>
<td>2</td>
<td>0.4</td>
</tr>
</tbody>
</table>

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

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

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
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.

CH1 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

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REFERENCES


[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

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