Examining Concentration Using Electroencephalography and Electromyography

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Abstract. Concentration is necessary for a person to study and carry out tasks. There is presently ongoing research into the improvement of the efficiency of execution, study, concentration, and relaxation. We have attempted to objectively quantify a person's level of concentration while studying as a first step towards improving the efficiency of study and learning. We correlated magnitudes of frontal midline theta rhythm (Fmθ; 4–7 Hz) and the frequency of blinking with self-reported levels of concentration and interest while a person assembled molecular models. Observations were carried out during periods of and while assembly tasks were carried out. For participants reporting that they were concentrating and interested, we found elevated Fmθ levels and increased rates of blinking, while participants reporting decreased levels of interest and concentration presented levels of Fmθ waves and rates of blinking similar to those observed during periods of rest.

Keywords: Concentration, Electromyography, Blinking, Electroencephalography

1. INTRODUCTION

Concentration is necessary to study and carry out tasks. When a person studies and carries out tasks, a personal mental condition like developing an interest arises. It has been attempted to devise interest to increase learning efficiency in school lectures. One example of this is the use of a molecular model kit to attract student interest and improve learning efficiency. Research has been conducted to prompt a relaxed state and increase the degree of concentration. We also use the aim of the development of support tools to increase the degree of concentration. This study is a basic attempt to establish and verify the method of concentration.

It has been reported that the 4–7 Hz band of the theta wave appears at the frontal midline when a person conducts mental labor such as concentration (Norimura Okamura, 2010). This is called frontal midline theta (Fmθ) from the site of its expression and is related to mental states such as attention, concentration, and interest. There is also a previous study showing the appearance of brain waves called α2 (10–13 Hz), the second half of the α wave (8–13 Hz), when a participant is shown to be in a state of concentration.

Blinking also increased in the state of concentration. There are voluntary blinks, carried out intentionally, reflective blinks, arising from external stimuli, and spontaneous blinks, occurring regardless of stimulus and intention. Among them, spontaneous blinks are said to depend on the subjective state, such as interest and concentration, and to reduce the amount of blinking when a person is in the concentration state (Kenroku Tuda and Naoto Suzuki, 1990).

In this study, we attempted to determine the degree of concentration to analyze and record shifts in the occupancy rate and increase or decrease blinking to observe transitions when our participants were doing tasks with molecular models.

2. ELECTROENCEPHALOGRAM AND BLINKING

In this section, we describe the electroencephalogram (Fmθ, α2) and blinking.

2.1 Electroencephalogram

The electroencephalogram (EEG) refers to data derived from surface electrodes or the potential change from deep electrodes in the brain and recorded on paper as a waveform. A large number of nerve cells are networked in the brain. Nerve cells use electrical signals when information is transmitted, which is called membrane potential. Membrane potential changes from moment to moment, causing a special potential change to exceed the threshold. This is the action potential. It is not possible to locate electrical signals if there is a slight inter-neuronal gap, if action potentials are generated by neurotransmitters released into the gap. Signaling is performed by postsynaptic potential, which is generated by released neurotransmitters transmitted to the transmission destination of neurons. These are obtained by measuring the electrical activity of neurons as a waveform, called the electroencephalogram. The electroencephalogram is classified by characteristics of activity, frequency band, and waveform, and by the measurement site on the scalp. They can be classified as the δ wave (0.5-4 Hz), θ wave (4-8 Hz), α wave (8-13 Hz), and β wave (13-30). In this research, we examine Fmθ, α2, which are expressed at the time of a concentration state.

2.1.1 Fmθ, α2

Fmθ (4-7 Hz) was thought to be an abnormal wave generated only in juvenile delinquents. Thereafter, such waves were determined to be normal in EEGs, since the θ rhythm from the frontal midline portion was also observed in healthy adults. Fmθ is expressed in continuing to perform mental work for a certain period of time; it has been implicated as the concentration of attention in people, expressed especially when in a state of attention concentration. In addition to this, there have also been reports of a brain wave called α2 expressed in the mental concentration state. The frequency of the α wave, between 8 Hz and 13 Hz, up to the first half, namely, 8-10 Hz is called α1, and the second half, namely, 10–13 Hz is called α2. α1 is expressed at rest, and α2 is to be expressed in a state of concentration.

2.2 Blinking

Blinking is the opening and closing movement of the eyelid. Blinking can be divided into three types. Voluntary blinking is those blinks that are deliberately done, such as winks; blinking because of external stimuli, such as debris flying into the eye or seeing a strong light, is called reflective blinking; and washing the cornea with tears to keep clean, correcting the blur of an object image, improving flow of aqueous humor, and causing tears to flow into the lacrimal duct from the conjunctival sac in the unconscious is called spontaneous blinking. Although spontaneous blinking was once thought to involve only the maintenance of the ocular environment, at present also it is affected by subjective mental states. In particular, the number of times it occurs is reduced in the state of concentration of attention.

3. MEASUREMENT METHODS AND SETTING OF THE EXPERIMENTAL DEVICES

We recorded EEG in parallel measurement with the number of blinks to objectively measure the degree of concentration. The apparatus used for this measurement is shown below.

3.1 Experimental devices

The following experimental devices were used:

- 8-channel multi-use biological amplifier, Biotop mini, East Medic Co., Ltd.
- Dish electrode Ag/AgCl (An inner diameter of 7 mm), NIHON KOHDEN Co., Ltd.

- Molecular Model Kit
- Molecular Model Kit Text
- Self-made trigger-generating apparatus
- Electrode paste: WEAVER and company Ten20 EEG Conductive Paste
- For exfoliating: Skin Pure, NIHON KOHDEN Co., Ltd.
- For skin cleansing: Ethanol(99.5)

3.2 Measurement methods

3.2.1 Measurement of the EEG

EEG is used as a means to understand the functional aspects of the brain. In recent years, the use of the electroencephalogram in clinical areas has been decreasing because of the improvement of diagnostic imaging and MEG-light measurement. However, these apparatuses require significant capital investment costs and operating expenses. Further, there are restrictions to their use, such as fixed location. EEG is used because it can reduce cost.

It is necessary to place electrodes on the scalp to perform EEG. The methods include using a disk electrode or a dish-shaped electrode with conductive paste or a special headgear fixed to the scalp; inserting a needle electrode into the skin; and using an electrode filled with electrolyte solution on the sponge fixed with the band. The advantage to these methods is their low cost, and there is no need for invasive procedures other than needle electrodes. The disadvantages are that detection value becomes extremely low compared with the surface of the brain, due to the fact that there is dura mater, spinal fluid, skull, and scalp between the electrodes and the brain tissue, noise occurs through the scalp, and there is contamination of muscle potential due to blinking, as well as other shortcomings. In addition to placing electrodes on the scalp, there is a method of arranging electrodes directly on the surface of the brain. This causes unobstructed contact between the electrodes and the brain, as compared to placing the electrodes on the scalp. This way, it becomes possible that the line with the observation of deep brain is suppressed noise. However, to place the electrodes, craniotomy must be performed, which is highly invasive.

In this study we use scalp electrodes to measure the electroencephalogram. In performing electrode arrangement, we used the International 10–20 system (EEG), which is generally used. The "10" and "20" refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front–back / right–left distance of the skull.

3.2.2 Blink count

Muscle fibers causing expansion and contraction undergo electrical signals from the brain and spinal cord to make a potential change. This potential change is referred to as muscle potential. It can be measured by electrodes attached to the skin. There are muscles on the face that make facial expressions, doing such aspects as blinking and opening and closing the mouth. These are referred to as facial muscles.

In this study, the measurement of the potential of the orbicularis muscle around the eye is used in the measurement of blinking in the facial muscles.

3.2.3 Electrode arrangement

In this study, electrode position at the time of electroencephalogram measurements was set in accordance with the arrangement of t the International 10–20 system, as shown in Figure 3.2.1. The placement of electrodes according to International 10–20 system. The derivation method was used as a reference electrode derivation method. On the left ear (A1) and the right ear (A2) are placed the reference electrode, and electrodes are placed on the C3 (left center), C4 (right center), O1 (left back of the head), and O2 (right occipital) as measurement sites. Also from the fact that Fmθ is expressed predominantly in the Cz (top) and Fz (frontal center), an electrode was placed on the Fm (frontal midline) to the position of the 10% crown from Fz.

Further, in this study, on the basis of the position of the iris, when the participant views front, there is an electrode placed on the top of the mewa muscle, so as to create a sandwich for the measurement of the number of blinks. The eye potential measuring electrode is placed on the participant above and below the right eye, outside the angle of the eye, and by the left ear (A1), as well as a GND placed on the forehead as shown in Figure 3.2.2.

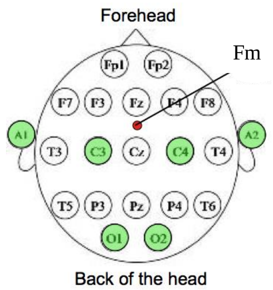

Figure3.2.1: Electrode arrangement

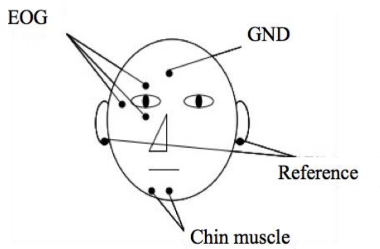

Figure 3.2.2: Electrode of face

4. METERING EXPERIMENT

4.1 Measurement

We used a measurement room in a laboratory. The room had closed doors, was kept to room temperature of 25℃, and was kept as much as possible without outside light during measurements. We placed a partition with the object to be used at rest in front of the subject, and thus the participant was unable to see the measuring person.

4.2 Experimental outline

In this experiment, we gave challenges and a resting task to the subject, who used a molecular model kit A. The EEG and ocular potential continued to record from the beginning of the experiment until the end. In analysis, we separated out the recorded data for each challenge interval. The participants performed a degree of concentration decision on the basis of the results of analysis, which was also compared with the survey results of measurement after the subject.

4.3 Participants

Nine healthy male students of the University of Fukui were the participants (median age 23.7). The participants were not informed of the content of the experiment beforehand.

4.4 Experiment content, flow

Measurements were carried out alternately prepared for four rests and three problems. Figure 4.4.1 shows the procedure.

We told the participants in the relaxed portion to make large movements, such as shaking the body, stretching, and yawning. We created a prepared object as a mark so that the participant was as much as possible unable to move the position of the line of sight at rest. Objects in which gave a yellow frame of the 29 cm square in white styrene board. This was placed at a distance of 150 cm from the subject's eye. We instructed the participants to look at the inside of the frame.

As the challenge, the participants carried out tasks using a molecular model kit. Three challenges were prepared. In task 1, participants were instructed to freely assemble as in a state in which the face down to be a molecular model kit. In task 2, we gave the participants a text after the description of the kit, and instructed them to assemble a molecular model within the measurement time. Within the time, we instructed them to perform a repetition. In task 3, we instructed the participants to freely assemble molecular models as in a text. Before the start of each task, we instructed the participants to look at the object just as they had at rest and signaled verbally the start and end of the task.

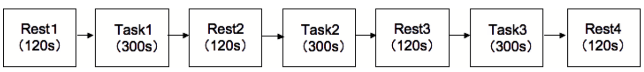

Figure 4.4.1: Experiment flow

5. ANALYSIS

5.1 Flow of analysis

A plurality of fluctuation components are mixed in the electroencephalogram.

When the data are subjected to a fast Fourier transform (FFT), it is possible to observe the characteristics spectrally resolved for each frequency. In this experiment, the data obtained were divided into measurements for each challenge section and subjected to a band-pass filter and divided in the band of Fmθ (4–7 Hz) and in the band of α2 (10–13 Hz). Afterward, FFT was carried out. At the same time, the number of blinks was counted.

5.1.1 Cut out of each challenge data

To find the trigger before and after the challenge entered to cut out the data obtained in the measurement for each interval, setting a threshold value on the program, a trigger value sequence is created containing the row number that exceeds the set value sequence. Based on the value stored in the sequence, each assignment section was cut out.

5.1.2 Frequency analysis

The methods of analyzing EEG are frequency analysis, the averaging method, independent component analysis, and principal component analysis. In this study, we employed frequency analysis using MATLAB.

Recorded data in each section were passed through a band-pass filter. This time measurement sites Fm, C_3, C_4, O_1, O_2 for Fmθ (4-7 Hz) band, α2 (10–13 Hz) band, extracting the entire area of the analyzed challenges interval (1–30 Hz) and determined power spectrum subjected to FFT (1000point) for each segment. FFT is because it is a 1000point, it began to processing by shifting 500point after the analysis of the 2 seconds (1000point).

5.1.3 Occupancy rate

EEG records potential generated as a waveform by activity of neurons and transmission between synapses and other synapses in the brain. It is not interrupted because activity is always taking place. However, if there is a change, such as a concentrated state, some activities related to this state occur almost at the same time. When this active state occurs, the proportion of the frequency band associated therewith is increased. This proportion is the occupancy rate. The occupancy rate was determined by dividing by the power spectrum of Fm in the whole range (1–30 Hz) of the power spectrum of Fmθ and dividing by the power spectrum of the whole range of O1 or O2 (1–30 Hz) of the power spectrum of O1 or O2. This was done for each of the challenges.

5.1.4 Count of blinking

The number of blinks was counted well below again exceeding the threshold (Figure 5.4.1). The average potential and the standard deviation in the interval were calculated from ocular potential data cut out from every challenge section measurement data for each subject, because of the threshold of the settings. We placed a threshold plus the 2.75 times the standard deviation of the calculated average potential. We also partnered the program to set the threshold for each challenge. Equation (5.4) is the equation of the threshold. A value of 2.75 of the formula is any value.

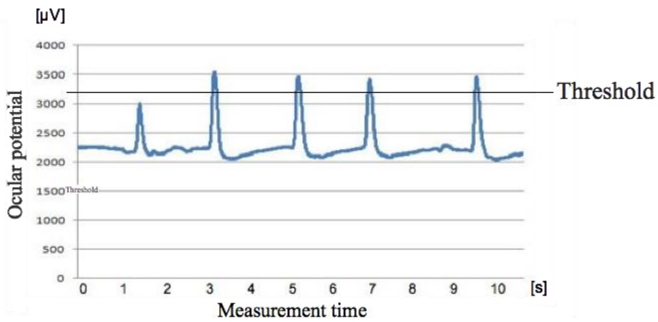

Figure 5.4.1: Ocular potential

Threshold = Average ocular potential + 2.75*SD (μ V) (5.4)

5.2 Rest state

In this experiment, we in structed the participants to each take a rest immediately after the start of the experiment, during task 1, task 2, and task 3, and after task 3. In the rest state in this experiment, it was required to perform no large movements such as standing up, shaking the foot, or twisting of the body. As it was required to as much as possible suppress the movement of the participants' eyes to allow natural blinking, we allowed participants to look at the object, as in 4.4. With regard to the significance of the rest state in this experiment to use the reference value as electroencephalogram at rest 1 in normal, challenge between the final resting state (rest 2 to 4) as a preparation period for moving to the next task, also provided for as an indicator to see the impact of the problems just before.

6. MEASUREMENT RESULTS

6.1 Occupancy of Fmθ

Shown in Figure 6.1.1 are the average occupancy rate changes for Fmθ in mF. The ordinate of the figure shows occupancy of each object, the horizontal axis represents the object, and this shows the average occupancy rate changes in all participants. Occupancy rate is assessed for rest 1 to reference. The occupancy rate of tasks 1–3 increased compared to rest 1. Task 2 gave an instruction to assemble the text "street." The rise in the occupancy rate was not much compared to the task 1 and task 3 that gave free assembly. For this time about α2, occurs suppression of α wave because of the task using hands, so it could not be verified because the changes were very small.

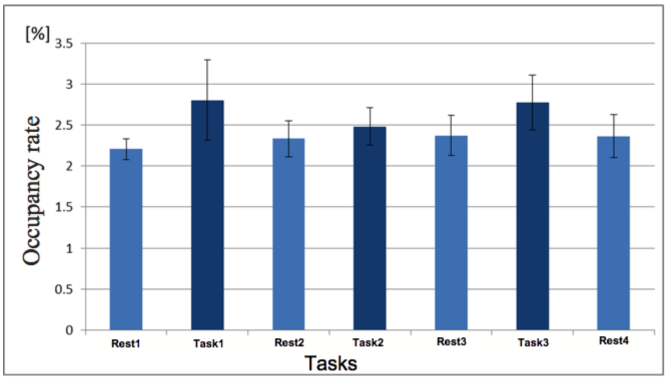

Figure 6.1.1: Occupancy rate

6.2 Blinking

Table1 shows the average blink frequency per minute for each rest and task. As shown, the blinking frequency was confirmed to be lower than the immediately preceding resting. The blink frequency of task 2 was more than the blink frequency of task 1 and task 3, and it was more than rest 1, which serves as a reference.

Table 1: The average blink frequency

Tasks	**Rest 1**	**Task 1**	**Rest 2**	**Task 2**	**Rest 3**	**Task 3**	**Rest 4**
Time/ Minute	**15.0**	**11.4**	**20.6**	**15.1**	**15.2**	**12.4**	**16.5**

6.3 Questionnaire

Figure 6.3.1 shows the questionnaire results from tasks 1 to 3. It has results concentrated in task 2 compared to task 1 and task 3. The number in task 2 showed the lowest interest.

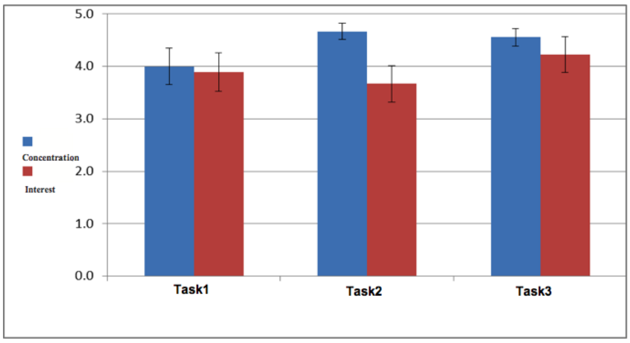

Figure 6.3.1: Questionnaire results

7. DISCUSSION

The participants were in an intensive state during the tasks, because an occupancy increase in percentage compared to rest 1 each challenge was observed from Figure 6.1.1. It can be said that occupancy at the time of rest increased with each passing challenge, because they are influenced by the concentration state of the subject.

Occupancy was reduced during task 2, for which the participants were instructed to assemble a text, compared with tasks 1 and 3, which involved free assembly. I think this result indicates that people are less likely to concentrate without interest when they are forced. Tracking changes in the blinking frequency, it can be imagined that the participants are in a concentrated state at the time of the task because of being decreased from just before the rest. Consideration of the cause of blinking a certain number of times in task 2, which showed a high blink rate compared to task 1 and task 3, shows that it is related to the interest of the participant as well as occupancy.

Given the results of the questionnaire based on the results of occupancy and blinking frequency, the results of the questionnaire showed more intensive work in task 2 than in tasks 1 and 3. This is a reverse result from the measures of occupancy and blinking. We consider that the task of the text is studying for a subject, there is a so-called feeling of class, where the task is concentrating on a subject. However, the free task gives a sense of play for the subject. In fact, the participants were unconsciously in a focused state when performing the free task, and it is thought that they did not have to be aware. We also look for the interest of the questionnaire; it is considered that the spiritual state such as interest has been affected to a centralized from that task 2 of the results is made to a value lower than the freedom task, tasks 1 and 3.

Given these results, it is considered that it is possible to objectively measure a state of concentration.

8. CONCLUSIONS

In this experiment we objectively observed degrees of concentration. In addition, we attempted to count blinks, because EEG was thought to be susceptible to disturbances. In addition, we also intended to compare with subjective measurements by means of questionnaire.

In this experiment, we were able to objectively measure the state of concentration. However, there is a need to continue gaining credibility by further increasing the number of the participants, as in future improvement; we feel the need for the improvement of tasks that can reduce the movements of hand movement and line of sight. Further, a result was obtained that the mental state of a person whose interest is involved in concentrating can be indicated. There is a need to also verify this.

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