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Improving Focus and Concentration in the Classroom while Studying with Lighting Arrangement and Brainwave Stimulation

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***Abstract*—The combination of brain wave frequency can be used to describe the level of attention and comfort of a person to a certain activity including the level of focus and concentration while studying in a classroom which represented by the increase of alpha and beta frequency band. These brain wave patterns can be manipulated using stimulation that resonates with the brain waves. The stimulation can be combined with the arrangement of the lighting system in the classroom to improve the result. A research was conducted to evaluate the brain wave frequency patterns of a participant in a classroom which was stimulated using binaural audio stimulation and a lighting arrangement to increase the focus and concentration of the participant. The results show that the alpha and beta frequency band represented as a relative wavelet energy are increased and distributed throughout the whole brain while the theta relative wavelet energy frequency band shows a trend of decrease.**

***Index Terms*— Electroencephalography, focus, concentration, lighting arrangement.**

I. Introduction

Electroencephalogram (EEG) can be used to detect the emotional state of a person by mapping it into the conceptual emotional dimension known as the Circumplex Model of Russell (Russel's Circumplex model). By using the circumplex model, the human emotions can be mapped to a two-dimensional quadrant consisting of Arousal (enthusiasm) and Valence (comfort) [1]. This emotional state can be measured to determine the level of interest and attention to a certain activity such as attending a lesson in the classroom. EEG has also been used to monitor the children with learning difficulties, i.e. difficulty in concentrating, people in severe stress, or difficulty to sleep (insomnia), which were combined with an application to check, and improve the brain function and the brain waves [2]. The result is supported by the research conducted by Corballis [3] which emphasizes that a formal education activates the left-brain hemisphere (logic and mathematics), while an informal education, courses and skills, such as music and art activate the right hemisphere (intuition and creativity).

Every person has a unique and consistent brain wave pattern. Its uniqueness can be seen from the combination of the five brain wave patterns (i.e. delta, theta, alpha, beta, and gamma) at a certain time [4]. The composition of brain waves also determines a person's level of consciousness. This means that the brain waves always change and have different patterns in various daily activities such as sleep, wake up, rest, and work. The brain wave pattern of each person is unique but does not mean that the pattern is constant all the time. By using certain "activation" and "stimulation" techniques, the composition and combination of brain wave patterns of the humans can be changed (manipulated) both by themselves and or with the help of others. These stimulations can increase focus and concentration on a learning activity, improve sleep function, and prevent insomnia [5].

Furthermore, the focus and concentration or attention of a person when attending a lesson in a class is also influenced by the level of lighting in the classroom [6]. It is stated that the lighting system has a positive influence on the level of concentration of a student. Therefore, it is important to have a proper lighting to improve focus and concentration in learning activity.

This paper described the method to improve the focus and concentration of a student while studying in a classroom by using lighting arrangement and brainwave stimulation using binaural audio which also becomes the novelties that is demonstrated in this paper. Using proper combination of lighting arrangement and the brainwave stimulation, the focus and concentration of a person while studying can be improved to a certain level.

II. Methods and Data Collection

The experiment was conducted in a small classroom which was equipped with a stereo sound system for brainwave stimulation, an audio video presentation equipment, and a lighting system that has 3 different types of illumination each with different color temperature: cool daylight (6500 K), cool white (4500 K), and warm white (3000 K). The lighting system has been measured to meet the lighting standard. The lighting standard used in this research is defined by the Illuminating Engineering Society (IES), which declares that a proper luminance for a workspace for studying activity is 300 Lux [7], [8].

To prepare a proper lighting for the experiment classroom, a simulation has been conducted using DiaLux software for the

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lighting design to determine the type and the number of the lamp to be used, and the layout of the lighting system so that the required illuminance standards can be achieved. Figure 1 shows the arrangement of the lighting system with 3 different types of illumination.

Fig. 1. The lighting system arrangement with 3 types of illumination.

Some participants were asked to watch a video presentation of mathematical subject in 3 consecutive sessions. After the end of each session, the participants were asked to solve some mathematical problems related to the presentation. The sessions were divided as follows: in the first session the participants were asked to choose 1 out of 3 different lightings that is the most comfortable for them. In the second session they were watching the next video using the selected lighting illumination without any stimulation. In the last session a brainwave audio stimulation was added to the room while the participants watched the video.

During all the presentation sessions, the EEG of the participants were recorded with 16 channel EEG equipment with 256 samples/sec. 10/20 international system was used for the EEG configuration as shown in Fig. 2. The sessions were also recorded with 3 video cameras from 3 different angles, that were at the rear left, front, and rear right side of the participants. The participants also filled some questionnaires after the last session to judge their arousal and valence emotion for each session.

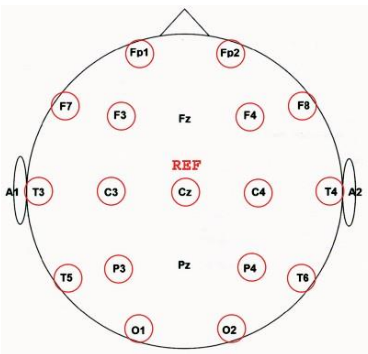

Fig. 2. 16 Channels EEG using 10/20 international system.

The recorded raw EEG was then pre-processed to remove artifacts. Each channel was filtered with 50 Hz notch filter and 5 to 45 Hz band pass filter, averaged to common reference [9].

To obtain the frequency distribution of the pre-processed EEG data, Discrete Wavelet Transform (DWT) was applied. The DWT has the advantages of multiscale zooming, multirate filtering, and time-frequency localization to extract the information from non-stationary EEG signals. According to [10] the DWT can be calculated as follows:

$$DWT(x(t);a,n) = \int_{-\infty}^{\infty} x(t)\ \frac{1}{\sqrt{2^a}} \psi\left(\frac{t-2^a n}{2^a}\right) dt \quad (1)$$

where $2^a\ n$ and 2^a are the time localization and scale respectively, while ψ denotes the mother wavelet function. In other word, the DWT is a filtering process using a *dyadically* shifted and scaled mother wavelet.

The wavelet energy $E(a)$ represents the energy of the wavelet coefficient localized at the a^{th} level of decomposition calculated as follows,

$$E(a) = |C_a|^2 = \sum_n C_a^2[n] \quad (2)$$

where C_a denotes the wavelet coefficients at the a^{th} decomposition level. C_a can be either wavelet approximation (x_{Aa}) or detail (x_{Da}).

The wavelet energy is then normalized against the total wavelet energy to obtain a probability mass function as follows,

$$p(a) = \frac{E(a)}{\sum_{k=1}^{K} E(k)}, \quad (3)$$

where K denotes the number of discrete wavelet decompositions, $p(a) \in \{0, 1\}$ and $\sum_a p(a) = 1$. The normalized measure is known as the *Relative Wavelet Energy* (RWE) [10].

In this experiment the daubechies 5 (db5) was used as the mother wavelet. The EEG frequency band can be computed using the wavelet detail coefficients giving:

a. 5th detail coefficients ≈ Delta (3 - 4Hz);
b. 4th detail coefficients ≈ Theta (5 - 8Hz);
c. 3rd detail coefficients ≈ Alpha (9 - 16Hz);
d. 2nd detail coefficients ≈ Beta (17 - 32Hz); and
e. 1st detail coefficients ≈ Gamma (33 - 64Hz).

The RWE of each frequency band of the EEG data can be represented in the form of histogram bar to compare the energy level of each frequency band. The Delta and Gamma bands were not included in the histogram as our concern in the research are only to the theta, alpha, and beta bands that related to the focus and concentration.

In the next step, the RWE of each theta, alpha, and beta frequency from all 16 channels are accumulated to obtain total RWE for each frequency band. The total RWE of each frequency band is then normalized and represented as histogram of total RWE for each frequency band. The total

RWE histogram are then compared between the RWE before stimulation and after stimulation to observe the effect of the stimulation.

The experiment used an audio stimulation using binaural algorithm [11], [12]. The binaural algorithm can be described as follows. Two frequencies are generated at the same time to stimulate the right and left ears where the frequency of both signals is matched with the brain wave frequency to be stimulated. For example, in the left ear a 200 Hz signal is generated, while at the right side a 200 Hz signal added with the brain waves frequency to be stimulated, i.e., 8 Hz alpha wave. Therefore, signal frequency in the right ear is 200 + 8 = 208 Hz. This process is continuously carried out between alpha and beta band frequency repetitively. As a result, the brain will respond to these different frequencies and resonate in the given frequency stimulation [13], [14].

III. Results and Discussion

The total RWE of 16 channels EEG for each frequency theta (θ), alpha (α), and beta (β) band before and after stimulation from 5 participants are represented in Table I.

TABLE I. Total RWE of 16 Channels EEG for Each Frequency Band Before and After Stimulation from 5 Participants

Participant	Total RWE of 16 Channels EEG for Each Frequency Band Before and After Stimulation					
	Before (%)			After (%)		
	θ	α	β	θ	α	β
1	68.4	17.9	13.7	58.8	22.7	18.5
2	65.9	19.3	14.8	54.2	31.5	14.3
3	63.0	25.7	11.3	35.6	46.4	18.0
4	70.0	23.3	6.7	62.1	28.7	9.2
5	43.6	24.9	31.5	18.7	63.0	18.3

Table I shows that the theta frequency bands for all the participant are reduced after the stimulation. On the contrary, the alpha frequency bands are increased for all 5 participants after the stimulation. While the beta frequency bands are increased for most of the participants with an exception for 2nd and 5th participant. Based on the answer in questionnaire, 2nd and 5th participant had the feeling of drowsiness at the last session. This might explain the reduction of the beta frequency bands. The difference of RWE for each frequency band are also represented in Table II. The difference is calculated by subtracting the RWE of after stimulation to the RWE before stimulation and compared to RWE before the stimulation which produce positive and negative difference in ratio. A negative difference shows a decrease of the RWE frequency band, while a positive difference presents an increase of the RWE frequency band, vice versa.

TABLE II. The Difference of RWE for Each Frequency Band Before and After Stimulation from 5 Participants

Participant	Difference (%)		
	θ	α	β
1	-16.3	21.0	26.0
2	-21.4	38.8	-4.3
3	-76.7	44.6	37.1
4	-12.6	18,7	27.1
5	-133.7	60.5	-71.9

Table II shows that the RWE of alpha frequency band is increased significantly for all the 5 participants. While the RWE of theta frequency band decrease moderately among all the participants. The difference the RWE of beta frequency band varies between the participants. The results suggest that the alpha frequency band has more impact in the alteration of the focus and concentration state.

Figure 3 illustrates the variation of RWE for each frequency band together with the difference for each RWE of the frequency band illustrated as the histogram of Total RWE from the first participant.

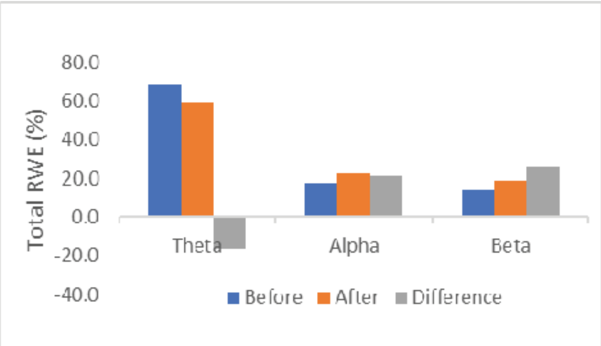

Fig. 3. Histogram Total RWE for each frequency band and its difference from the first participant.

Further analysis was conducted by mapping the RWE frequency band of each channel to the top view of the scalp to illustrate the distribution of each frequency on the scalp before and after the stimulation. The illustration is shown in Fig. 4 which was developed from the EEG data of 4th participant.

Figure 4 shows that the distribution of the theta frequency band before the stimulation is moderate and is decreased after the stimulation.

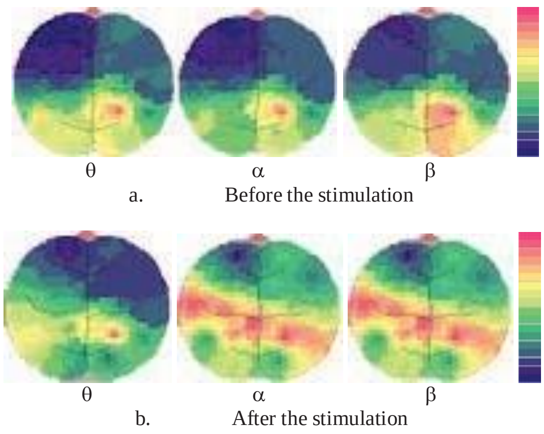

Fig. 4. The mapping of RWE frequency band to the top view of the scalp before and after stimulation.

Conversely, the distribution of alpha band is less before the stimulation. However, it is increased after the stimulation. The similar circumstance occurs to the beta frequency band which is also increased after the stimulation. Therefore, the analysis of the mapping supports the results that has been discussed in Table I.

Further analysis of the mapping shows that the distribution of the RWE frequency band before the stimulation only take place on the back side of the scalp which then change in effect of the stimulation and the distribution of the RWE frequency bands expand to almost the area of the scalp. This means that the stimulation also affects to the whole area of the brain.

IV. Conclusions and Further Work

The research that has been conducted to improve the focus and concentration of a person by using the lighting arrangement and audio stimulation shows positive results. The increase of the focus and concentration are related to the relative wavelet energy of each frequency which shows a trend of increase for the alpha and beta frequencies and the decrease of theta band. The rise of alpha frequency is more dominant than the beta band, while the decline of theta band is generally taking place. The effect of the stimulation also activates the whole at area of the brain which is inline with the increase of alpha and beta band and the decrease of theta band.

Further direction is to implement the proposed method to a more significant numbers of participants to validate the results. It will also implement to a more varies of courses such as science, language, and social study in a more spacious classroom.

Acknowledgment

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Improved Ibu Endah-Pak Henry

by Endah Setyaningsih

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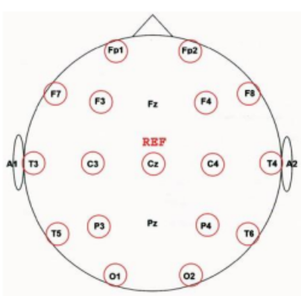

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4	-12.6	18.7	27.1
5	-133.7	60.5	-71.9

Table II shows that the RWE of alpha frequency band is increased significantly for all the 5 participants. While the RWE of theta frequency band decrease moderately among all the participants. The difference the RWE of beta frequency band varies between the participants. The results suggest that the alpha frequency band has more impact in the alteration of the focus and concentration state.

Figure 3 illustrates the variation of RWE for each frequency band together with the difference for each RWE of the frequency band illustrated as the histogram of Total RWE from the first participant.

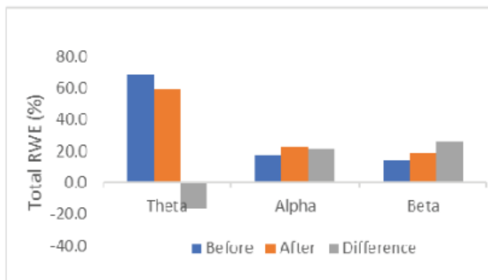

Fig. 3. Histogram Total RWE for each frequency band and its difference from the first participant.

Further analysis was conducted by mapping the RWE frequency band of each channel to the top view of the scalp to illustrate the distribution of each frequency on the scalp before and after the stimulation. The illustration is shown in Fig. 4 which was developed from the EEG data of 4th participant.

Figure 4 shows that the distribution of the theta frequency band before the stimulation is moderate and is decreased after the stimulation.

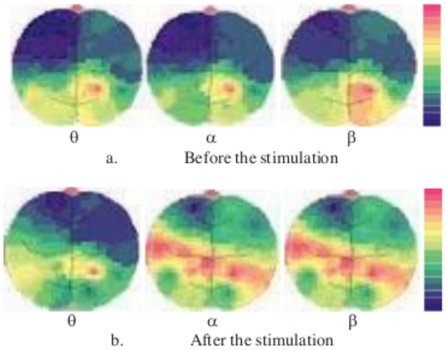

Fig. 4. The mapping of RWE frequency band to the top view of the scalp before and after stimulation.

Conversely, the distribution of alpha band is less before the stimulation. However, it is increased after the stimulation. The similar circumstance occurs to the beta frequency band which is also increased after the stimulation. Therefore, the analysis of the mapping supports the results that has been discussed in Table I.

Further analysis of the mapping shows that the distribution of the RWE frequency band before the stimulation only take place on the back side of the scalp which then change in effect of the stimulation and the distribution of the RWE frequency bands expand to almost the area of the scalp. This means that the stimulation also affects to the whole area of the brain.

IV. Conclusions and Further Work

The research that has been conducted to improve the focus and concentration of a person by using the lighting arrangement and audio stimulation shows positive results. The increase of the focus and concentration are related to the relative wavelet energy of each frequency which shows a trend of increase for the alpha and beta frequencies and the decrease of theta band. The rise of alpha frequency is more dominant than the beta band, while the decline of theta band is generally taking place. The effect of the stimulation also activates the whole at area of the brain which is inline with the increase of alpha and beta band and the decrease of theta band.

Further direction is to implement the proposed method to a more significant numbers of participants to validate the results. It will also implement to a more varies of courses such as science, language, and social study in a more spacious classroom.

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