Binaural Beat Effect on Brainwaves based on EEG

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***Abstract*— This research focuses on the effects of binaural beat entrainment to delta and theta brainwaves. This paper presents the results that were collected from an experiment performed on 33 subjects. The EEG signals recorded from the experiment are based on two stages, specifically when the subjects are doing nothing (before binaural beat) and after binaural beats entrainment. Theta wave relates with deep relaxation, day-dreaming and memory. Meanwhile Delta wave associates with deep sleep. Stress is a challenging condition that commonly happens in human life. There are various ways to cope with stress and one of them is to spend time for relaxation. Besides that, binaural beat can be used as a substitute for meditation to alleviate the stress. Binaural beat is the rhythmic stimulus which is generated to produce the desired audio frequency with the intention to make brainwave to follow that frequency. In the end of our research, the result shows that Theta brainwave increases after listening to binaural beat. Although the Delta brainwave is not really affected in this experiment, there is still an increment of delta brainwave after listening to binaural beat. The result shows that binaural beat affected on delta and theta brainwaves.**

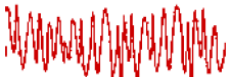
Keywords*— *Electroencephalography (EEG), Binaural beat, Stress

I. INTRODUCTION

Electroencephalography (EEG) gives a noninvasive way of measuring brainwave activity from sensors placed on the scalp of the human head [1]. Human brain has millions of neurons and due to electrical activity of these neurons, small signal voltages generated on the surface of the human scalp. These small signal voltages are Electroencephalography (EEG) signals which is also known as brainwaves [2]. Neurons of the human brain play important roles in processing information as the flow of electrical currents across neurons' membranes is changed when the processing information is happened. These changing currents generate electric and magnetic field that can be recorded from the surface of the scalp. In order to measure the electric fields, small electrodes function as sensors are attached to the scalp. Since the potentials between different electrodes are small, this signal is then amplified and recorded as the electroencephalography (EEG).

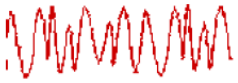
There are four (4) dominant frequency bands of brainwaves which are Alpha, Beta, Delta and Theta. The brainwaves that are measured by EEG have a rate of oscillation in cycles per second or hertz (Hz) [3]. Different types of brainwaves that have different rates of oscillation are associated with distinctive brain functions. Beta waves are fast brainwaves that are associated with thinking, concentrating, and processing information. Meanwhile, Alpha waves are associated with quiet and relaxed attention. The slower Theta waves are associated with memory, deep relaxation, and day-dreaming [4]. Thus, Delta waves are the slowest brainwave and associated with deep sleep [4]. This brainwave pattern is important in exploring the consciousness state [3].

i. Beta waves



Frequency (Hz): 13-40
Amplitude (μV): Lowest

ii. Alpha waves



Frequency (Hz): 8-12
Amplitude (μV): Low

iii. Theta waves

Frequency (Hz): 4-7
Amplitude (μV): High

iv. Delta waves

Frequency (Hz): 0.1-3
Amplitude (μV): Highest

Figure 1. The shape, frequency and amplitude of the brainwaves [5, 6]

The alpha brainwave is the most frequently investigated when experiment of binaural beat entrainment is conducted. For example, there is research about behavior of EEG alpha asymmetry when stress is induced and binaural beat is applied [7]. Since there is still no research focuses on Delta and Theta brainwaves when binaural beat is applied, this research will focuses on these two brainwaves.

Stress is related to biological and psychological of the human condition. In general, stress is defined as the body's reaction to perceived mental, emotional or physical distress [8]. This negative emotional scales influence on health, professional performance and everyday routine of personal in a bad way [9]. Stress will bring worse consequences if proper counter measure is not taken to reduce the stress level

of the person to normal level. The meditation is one of the common ways to reduce stress that people usually practice in their everyday life. The binaural beat which is one type of brainwave entrainment can be a substitute way to replace meditation process but gain the same effect [7].

The binaural beat sound is one auditory stimulation technique for brainwave entrainment that consists of two slightly different frequencies of tones presented to each ear [10]. The result of the interaction of the two tones within the auditory brainstem is equal to the difference between the two frequencies and it is known as the third frequency [10]. This interaction result entrains the electrical rhythms of the brain vibration at the same frequency hence brain wave will start to synchronize to the third frequency [10]. This is how the brain wave activity reacts and responds to the binaural beat sounds. The brainwave entrainment is refers to the use of rhythmic stimuli with the intention of producing a frequency-following response of brainwaves to match the frequency of the stimuli [11]. Brainwave entrainment is convenient in helping relieving anxiety and stress [7].

This paper is to investigate the effect of binaural beat to delta and theta brainwaves.

II. Methodology

A. Stimuli

The binaural beat audio that will be adopted to entrain the brainwave frequency towards the desired state such as relaxation or enhanced attention, is generated by using the Brain Wave Generator. There are more than 20 built-in brain wave entrainment programs specified for different purposes offered by Brain Wave Generator [12]. The pre configuration setting that was used in the conducted experiment is the Meditation 2 (deep) audio, which was aiming at inducing a meditative or relaxed state of mind [12]. The produced frequency of this preset audio has been validated in the laboratory to be 10 Hz [7]. A sound isolating earphones is used as a precaution to make sure that any external noise is blocked and the sound transferred from the laptop is isolated.

The EEG equipment used to collect the brainwave data from test subjects in this research is the EMOTIV EPOC that has 14 electrodes and operates as a wireless EEG system [13]. The sampling rate of this device is 128 Hz. Figure 2 shows the EMOTIV EPOC used in this research. Meanwhile, Figure 3 shows the placement of EMOTIV EPOC EEG system during data collection.

Figure 2. Emotiv neurohead set unit

Figure 3. EPOC EMOTIV EEG electrodes from side view

B. Subjects

33 healthy right handed volunteered subjects participated in this research (11 males and 22 females). These participants are the students of Universiti Teknologi MARA, Shah Alam. They were foretold not to consume any caffeine products and drugs to ensure the genuineness of the result for the research. The subjects are generally informed about the protocol of the research before signing the consent form and answering the questionnaire. The Depression, Anxiety and Stress Scale (DASS) questionnaire is used in this research to indicate and measure the stress level of the subject [14].

C. Data Collection Procedure

The overall procedure of the experiment is outlined as followed:

i. Subject needs to fill in and sign the consent form.
ii. The Depression, Anxiety and Stress Scale (DASS) questionnaire need to be answered and completed.
iii. In a dimly light conditioned room, the subject was asked to sit comfortably.
iv. The subject was told to close their eyes during the whole sessions. Subject was asked to wear eye mask to avoid stress around eyes muscles while closing their eyes for this certain period.

The flow of the process during data collection is summarizing as in Figure 4.

Figure 4. The flow process of procedure of EEG recording

D. Signal Processing and Data Analysis

The raw EEG data recorded was processed offline using a program developed using MATLAB. The raw data were first gone through an artifact remover process. This process plays an important role in ensuring that the EEG data is clean from artifacts. These artifacts are in the form of signals from eye movement and they can affect the cognitive process thus cause substantial data loss [7]. The data were then further analyzed using Microsoft Excel.

III. Result And Discussions

In this section, result from 33 subjects will be discussed. Subjects are categorized into 2 groups; stress and normal. These groups are based on the result of DASS questionnaire.

TABLE I. The Result Of DASS Questionnaire

Normal	Stress	Total
14	19	33 subjects
42%	58%	100%

Table 1 shows that 58% of the total subjects are identified to be stress meanwhile the other 42% are in normal condition. It is found that more than 50% of subjects are categorized into stress group based on score obtained from the DASS questionnaire. The main cause for such observation to happen is most probably due to the fact that experiment was conducted right after the students' final examination. The subject may still experience stress from their final examination.

In Figure 5, the recorded Delta brainwave of subjects when doing nothing (before listening to binaural beat) and after listening to binaural beat is shown. Delta brainwave both in left and right hemisphere of the brain is found to increase a bit after listening to binaural beat. As claimed in [4], Delta brainwave is associated with deep sleep. The experiment has shown that binaural beats entrainment has given the same effects as meditation, where it helps the subject to relax. While listening to binaural beat for certain time without doing anything else, the subjects most likely became very sleepy and relax. Since the EEG data for doing nothing and after listening to binaural beat are recorded while all the subjects are awake, the Delta wave are not really sufficient. The Delta wave that is dominant during deep sleep is not really affected in this experiment.

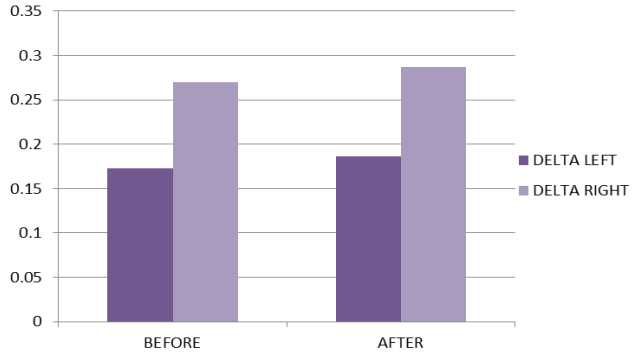


Figure 5. Delta brainwave before and after listening to binaural beat

From Figure 6, the Theta brainwave before listening to binaural beat (doing nothing) and after listening to binaural beat is plotted. Both Theta brainwave in left hemisphere and right hemisphere of brain are increases after listening to binaural beat. Theoretically, Theta brain wave is associated with memory, deep relaxation, and daydreaming [4]. The subject supposedly feel relax after listening to binaural beat for a period of time as their brainwave become synchronize with the third frequency. Since they have achieved the state of deep relaxation, they can be easily to enter day-dreaming state, thus the Theta brainwave most likely increases after listening to binaural beat.

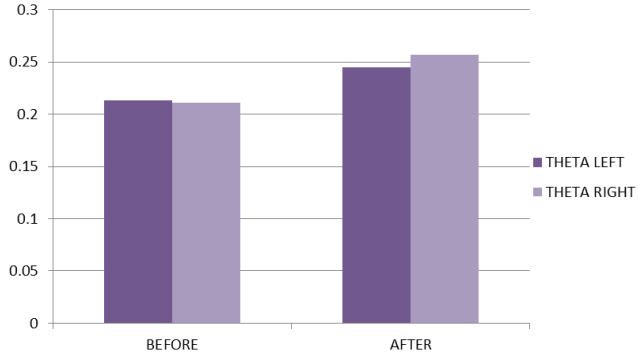


Figure 6. Theta brain wave before and after listening to binaural beat

From Figure 7, 20 subjects were found to have their Delta brainwave increases meanwhile the rest of 13 subjects' Delta brainwave are decreases. The increment of Delta brainwave after listening to binaural beat in percentage is 61% and the decrement of Delta brain wave is 39%. The decrease in Delta brainwave happened most probably because there are subjects that are not able to relax as all the subjects for this experiment are first timer in listening to binaural beat. Furthermore, the experiment is conducted with requirement that all the subjects need to be awake while EEG data is recorded, thus Delta wave is only dominant during deep sleep.

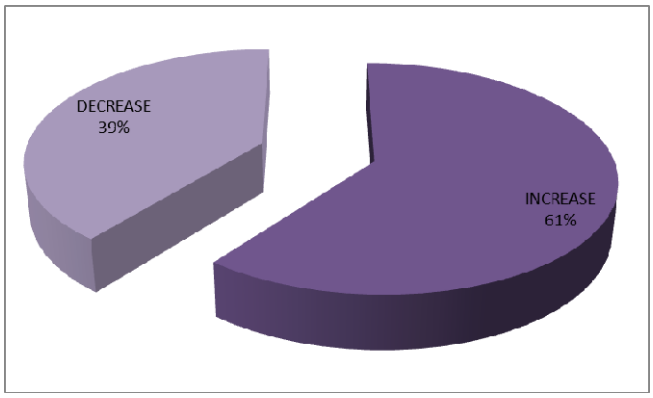


Figure 7. Distribution of Delta brainwave after listening to binaural beat

As presented in Figure 8, the percentage of increased Theta brainwave is 76% thus the decreased Theta brainwave is 24%. From the total of 33 subjects that participated in the experiment, there are 25 subjects are increase in their Theta brainwave and 8 people are not. There are some of subjects that are not relaxed and enable to daydreaming. Hence, when subjects not in deep relaxation and daydreaming state, their Theta brainwave decreases. The subjects need to be applied with binaural beat for a few times before obtained the optimum effect of relaxation.

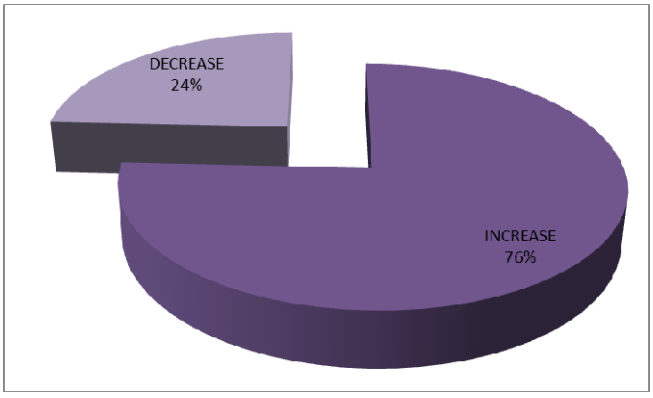


Figure 8. . Distribution of Theta brainwave after listening to binaural beat

IV. Conclusion

In this paper, the effect of binaural beat to Delta and Theta brainwaves is investigated. Based on the conducted experiments on 33 subjects, we can conclude that most of subject's Theta brainwave is increased after listening to binaural beat. Although the Delta brainwave is not really affected in this experiment, there is still an increment of delta brainwave after listening to binaural beat. 61% of the subjects experienced the Delta brainwave increment; meanwhile the remaining 39% subjects experienced the decrement. Furthermore, 76% of Theta brainwave is increases and 24% are decreases after listening to binaural beat. This study can be improved in the future by increasing the number of subjects participates in the experiment and the data will become more accurate.

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