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Influence of Mozart Music and White Noise on Brain Rhythm Power during Visual Working Memory Task

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ABSTRACT

Background: Peoples believed that listening to acoustic stimuli are able to release stress and enhance the cognitive processing. This study aim to determine the effect of Mozart's music and white noise has on brain rhythm power during memorizing process using electroencephalography (EEG). Twenty five subjects have been selected to undergo the experiment. They were required to memorize the task in two minutes at three different conditions; silence, listening to Mozart's Sonata K. 448 and pure white noise. Electroencephalography modality with 10-20 placement electrode was used to record the brain signal. There were 8 channels selected for data processing and analysis. The power of gamma, beta, alpha and theta rhythm was extracted from the brain signal by using discrete wavelet transform approach at channel Fp1, Fz, F8, T3, T4, Pz, O1 and O2. Delta rhythm was excluded, since it is mostly affected by noise. The electrooculography (eye movement and blinking) and electromyography (muscle movement) artifact that contaminated with EEG signal was removed by using stationary wavelet transform filter. The alpha and theta rhythm mostly influence in this study, since it has relation with the acoustic stimuli and working memory task. The Mozart music and white noise have different effect on EEG channel, whether it has increased or decrease the power of brain rhythm. Listening to Mozart's music has increase the brain rhythm activity, whereas the white noise has decreased its relative to the control condition. The percentage correctness of task response in control condition were 84.0%. Meanwhile, during listening to Mozart's music was 90.8% and 93.6% in white noise condition. Thus, the subject can perform better during listening to white noise compare to Mozart's music.

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INTRODUCTION

It has long been known that listening to the specific sound during working or study time able to reduce stress, enhance the creativity and improve the brain function (Xuemin Zhang *et al*., 2009). Based on the positive influence of the acoustic stimuli on the human brain, it attracts the researcher to do a study by using various types of sound. Generally, their aim was to investigate the sound effect on brain activity whether it can give the positive or negative influence on memory performance. Mozart's music and white noise are examples of sound that widely used by researchers in order to determine its effect on brain function. Mozart music can be categorized as a classical music, whereas white noise can be defined as a sound that is artificially created by combining all audible frequencies in equal amounts (Ravi Mehta *et al*., 2012). Previous research has found that the Mozart music and white noise have positive and negative influence on memory performance, which cause changes in brain activity (Leonid Perlovsky *et al*., 2013, Goran BW Soderland *et al*., 2010, Weina Zhu *et al*., 2008).

The study that has been done on epilepsy people has found that by listening to the Mozart's music the epileptiform discharges were significantly decreased (Lun-Chang Lin *et al*., 2014). The power of alpha, theta and beta power is significantly decreased after the people listen to the Mozart music (Lun-Chang Lin *et al*., 2014). It has enhanced the performance of people in solving the spatial rotation tasks, whereas for the visual oddball task, it give positive influence on involuntary attention and negative influence on voluntary attention (Weina Zhu *et al*., 2008) (Norbert Jausovec *et al*., 2006). The exposure of white noise during solving episodic verbal free recall test give positive influence for inattentive children, whereas it give negative influence for attentive children (Goran BW Soderland *et al*., 2010). The other study that involves the verbal memory task and visuo-spatial working memory task, the white noise has increase

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the brain activity in the right side compare to the left side (Goran BW Soderland *et al*., 2009, Stina Flodin *et al*., 2012). The noise gives positive influence for young people compare to old people in solving the problem (Goran BW Soderland *et al*., 2009, Stina Flodin *et al*., 2012). Up to now, there is only limited study on the effect of white noise and Mozart music on brain rhythm power has been reported in the literature. The purpose of the present study is to determine the effect of sound stimuli with the visual working memory task on alpha, beta, gamma and theta rhythm power based on wavelet approach. Besides that, the relation between changes of power brain rhythm to the performance of subjects in memorizing the task also investigated.

Brain is one of the most complex organ in the human body which has an interest the thousands of researchers to know it function deeply. Generally, it can be divided into four main major regions that are cerebral hemisphere, diencephalon, brain stem and cerebellum. The cerebral hemisphere is one of the brain parts that always selected in order to examine the way of the brain working. Cerebrum or cerebral hemisphere is the center for movement initiation, conscious awareness of sensation, complex analysis, and expression of emotions and behavior (Tianbao Zhuang *et al*., 2009). It consists of four lobes that are parietal, occipital, temporal and frontal. Brain rhythm or oscillatory activity of electroencephalography signal can be categorized into 5 that are delta (0 – 4 Hz), theta (4 – 8 Hz), alpha (8 – 16 Hz), beta (16 – 31 Hz) and gamma (32 – 63 Hz) (Saied Sanei *et al*., 2013). However, the delta rhythm always excluded due to consider it as a noise (Kwang Shin Park *et al*., 2011). Table 1 shows the description of each brain rhythm. Nowadays, there are various brain imaging techniques that have been invented in order to record or capture the brain image and activity such as positron emission tomography (PET), magnetic resonance imaging (MRI), magnetoencephalography (MEG), computed tomography (CT), electroencephalography (EEG) and etc. However, among the modality the electroencephalography widely used, since it is painless and harmless to the people, able to record the brain signal in a short time, low cost and easy to be used.

Table 1: Human Brain Rhythm (Saied Sanei *et al*., 2013).

Brain Rhythm	Descriptions
Theta (4 – 8 Hz)	Deep relaxation, meditation, focus, creativity, hypnagogic state
Alpha (8 – 16 Hz)	Light relaxation, positive thinking, fast thinking
Beta (16 – 31 Hz)	Increase mental ability, focus, alertness, IQ, fully awake, stress and anxiety
Gamma (31 – 63 Hz)	Associated with information rich task processing and high frequency

Raw electroencephalography signal usually contaminated with artifacts due to it small amplitude. The most common types of artifacts that present in EEG signal are electrooculography (eye movement and blinking) and electromyography (muscle movement). Selecting a good filter is an important criteria, since it affects the actual result during analyzing stage. The important information might be loss if the filter use is not suitable. Wavelet approach that has been introduced by Jean Morlet in 1982 is one of the effective approaches that can be used to remove the artifact in EEG signal without losing the time invariant property (Mario Elvis Palendeng, 2011). It can be divided into three which are continuous wavelet transform (CWT), discrete wavelet transform (DWT) and stationary wavelet transform (SWT). In this present study, we use the Daubechies order 3 (db3) mother wavelet of stationary wavelet transform for removing the artifacts and Daubechies order 4 (db4) of discrete wavelet transform for extract the brain rhythm of 500 Hz EEG signal. The db3 mother wavelet of stationary wavelet transform filter is used due to it has the spiky characteristic which can be found in electrooculography and electromyography artifact (Mario Elvis Palendeng, 2011). Due to this characteristic, this type of filter able to remove the artifact effectively (Mario Elvis Palendeng, 2011).

Discrete wavelet transform is an approach that analyzes the signal at different frequency bands, with different resolutions by decomposing the signal into a coarse approximation (An) and detail (Dn) information (Abdulhamit Subasi, 2007). Fig. 1 shows the decomposition of EEG signal at different frequency bands. The electroencephalography signal is passed through the low pass and high pass filter to be decomposed into the required frequency band. Since in this present study the dominant frequency is 500 Hz, so the decomposition level 7 is used for extracting theta, alpha, beta and gamma rhythm. The mother wavelet that suitable is Daubechies wavelet order 4 due to it’s more appropriate to detect changes of EEG signals and give better accuracy than the others (Abdulhamit Subasi, 2007).

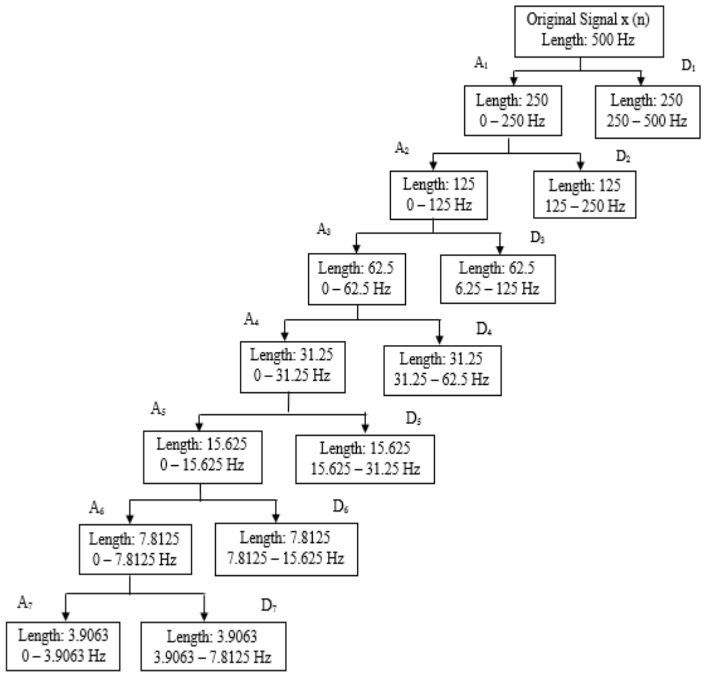

Fig. 1: Discrete Wavelet Transform Decomposition Level Of 500 Hz EEG Signal At Different Approximation And Detail Coefficients.

Methodology:

Subject:

Twenty five subjects of age 20 – 26 years old were selected in this study based on the mini-mental state examination (MMSE) score. The MMSE aims to determine their memory condition, whether bad or good. Only the subject with good memory is chosen in this study (score: ≥ 25 out of 30 points) (B. Geethanjali *et al*., 2012). They were in a healthy condition without visual and hearing condition. They were divided into two groups.

Stimuli:

The stimuli that use in this study included visual working memory task and three different conditions. The task that used in this study is based on (Xuemin Zhang *et al*., 2009) with some modification. In (Xuemin Zhang *et al*., 2009) they use 15 pictures whereas in this present study only 10 pictures was use. The task was used numbers and image in order to avoid the probability that the language of materials affect the subject's performance (Xuemin Zhang *et al*., 2009). The subjects were required to memorize the task at three different conditions which are silent (control), listen to Mozart's music (Mozart Sonata K. 448) and listen to white noise (pure white noise). The volume was controlled between 45 to 55 dB, in order to eliminate the effect of volume (Xuemin Zhang *et al*., 2009) . Fig. 2 shows the task that uses in this study at different conditions.

Experimental Procedure:

The subjects were divided into two groups. First group need to memorize the task in the control condition, follow by listening to Mozart's music and lastly in white noise condition. Meanwhile, the second group was memorized the task in control condition, listening to white noise and listening to Mozart's music condition. The order of condition was changed reversely to counterbalance the effect of sound stimuli on subject performance (Norbert Jausovec *et al*., 2006). They were given two minutes for memorizing the task before recalling back after a thirty second rest. The subject was relaxed in about five minutes after entering the laboratory room. Then, a survey questionnaire was provided. An instruction about the experiment was given to them before starting. The flow of the experiment and task was created by using movie maker software in order to fix the rest, memorizing and recalling time among the subjects. The flow of experiment was:

1. The subject memorized the task in 2 minutes at silence condition. The brain signal was recorded.
2. Subject rested for 30 seconds.
3. Recalling the task in 2 minutes.
4. Subject rest while seen the scenery pictures on laptop screen in about 3 minutes.
5. Listening to the Mozart's music about 5 minutes to make familiar with the sound.
6. They memorized the task while listening the music in 2 minutes. The brain signal was recorded.
7. Subject rested for 30 seconds.
8. Recalling the task in 2 minutes.
9. They were resting for 3 minutes while looking the scenery pictures.
10. Listening to the white noise about 5 minutes to

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make familiar with the sound.

11. Memorized the task in 2 minutes while listening to the white noise. The brain signal was recorded.

12. Rested for 30 seconds.

13. Recalling the task in 2 minutes before ended the experiment.

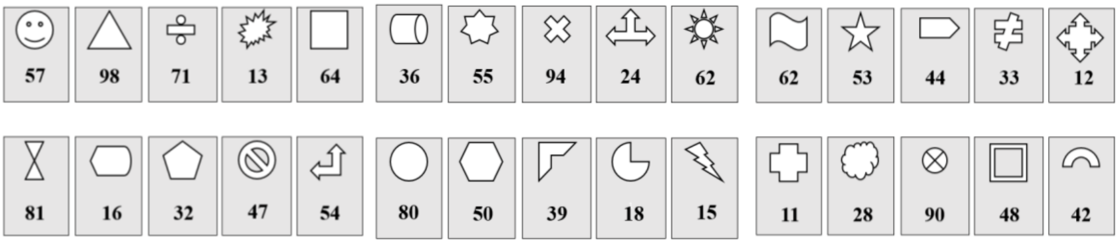

Fig. 2: Assessment Task (A) Control Condition (B) Mozart's Music Condition (C) White Noise Condition (Xuemin Zhang *et al*., 2009).

Data Acquisition and Processing:

The brain signal was recorded by using 10-20 placement electrode of electroencephalography machine (Neurofax 9200). Fig. 3 shows the arrangement of electrode for 10-20 placement system. Among the 19 electrodes only 8 channels were selected for processing and analyzing stage. These channels were chosen due to it has relations with the task and sound stimuli that used in this study. The channels are Fp1 (attention), Fz (working memory), F8 (emotional expression), T3 (verbal memory), T4 (emotional memory), Pz (cognitive processing), O1 (visual processing) and O2 (visual processing) (Horst H. Mueller, 2007). The raw EEG data were saved in ASCII format before loaded into the MATLAB software.

Then, the artifacts in EEG signal were removed by using db3 mother wavelet of stationary wavelet transform. The clean signal was passed through db4 mother wavelet of discrete wavelet transform at 7 decomposition to produce the gamma (D4), beta (D5), alpha (D6) and theta (D7) rhythm. Fig. 4 shows the brain rhythm from a subject. Then, the power of brain rhythm was determined at Fp1, Fz, F8, T3, T4, Pz, O1 and O2 channel. The power of brain rhythm can be defined as (Sirvan Khalighi *et al*., 2013):

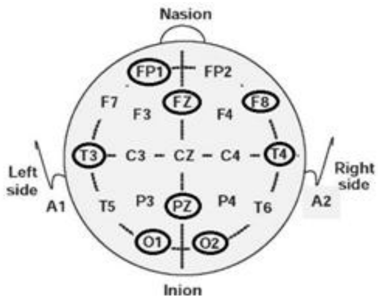

Fig. 3. 10-20 Placement Electrode (B. Geethanjali *et al*., 2012).

$$P_i = \frac{1}{n}\sum_{j=1}^{N} \left| X_{ij} \right|^2, i = 1, 2, 3, \ldots . l \quad (1)$$

where, P_i is the power of the detail and approximate at decomposition level i, $i = 1,2,3,\ldots . l$ is the wavelet decomposition level from level 1 to level l, N is the number of the coefficients of detail or approximate at each decomposition level and n is the length of the detail or approximate (Sirvan Khaligh *et al*., 2013). Table 2 shows the decomposition of EEG signal into different frequency band with dominant frequency 500 Hz.

Table 2: Decomposition Level of 500 Hz Discrete Wavelet Transform.

Frequency Range (Hz)	Decomposition Level	Frequency Band
250-500	D1	Noise
125-250	D2	Noise
63-125	D3	Noise
31-63	D4	Gamma
16-31	D5	Beta
8-16	D6	Alpha
4-8	D7	Theta
0-4	A7	Delta

RESULTS AND DISCUSSION

Electroencephalography signal power is one of the features that important to be extracted, since it determine the activity of the brain. EEG power can be defined as a measure that reflects the capacity or performance of cortical information (Wolfgang Klimesch, 1999). The EEG power of brain rhythm was extracted in this study in order to determine the effect of Mozart's music and white noise on brain rhythm activity during memorizing visual working memory task. Relative to the control condition, there were widespread increases and decreases in gamma, beta, alpha and theta rhythm at Fp1, Fz, F8, T3, T4, Pz, O1 and O2 channels during listening to the sound stimulation. Table 3, 4, and 5 show the mean (standard deviation) of brain rhythm power at selected channel. A paired samples *t*-test analysis was used to analyze the mean power of brain rhythms and the score result, whether having significant difference or not between sound stimulation and control condition.

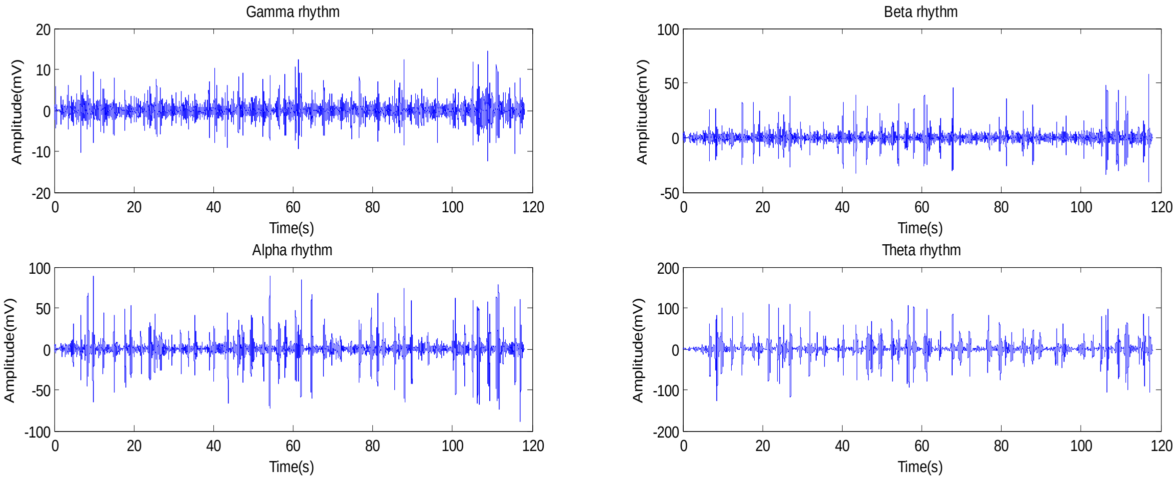

Fig. 5. Example of brain rhythms from one subject.

Gamma and Beta Rhythm Power:

Listening to the Mozart's music has increased the power of the gamma and beta rhythm relative to the control condition. There was a significant difference in gamma (p = 0.01 < 0.05) and beta (p = 0.04 < 0.05) rhythm were found. Meanwhile, the power of gamma and beta rhythm was decreased when subject listening to the white noise. There was no significant difference were found for white noise condition (gamma: p = 0.95 > 0.05, beta: p = 0.40 > 0.05) relative to the control condition. Gamma rhythm was highly found in brain signal during people facing with higher cognitive task, such as solving the math arithmetic and activities that require more thinking. Since, in this study the memorizing task was used, so the power of gamma rhythm was lower compared to beta, alpha and theta rhythm. Based on the average value the power of gamma and beta was lower during in white noise condition compared to Mozart's music condition. It indicates that the gamma and beta activity was less during subject memorize the task in white noise condition. Beta rhythm is mostly found in brain signal when the people in stress, focus, anxiety and alertness condition. The lower power of beta rhythm means subject is in less pressure condition and does not require much attention. The white noise condition is able to reduce the stress level and attention compared to Mozart's music condition. In Mozart's music condition the beta rhythm was higher relative to control and white noise condition. The Mozart's music has disturb the concentration of subjects in memorizing the task, thus the power of beta rhythm was increasing.

Alpha and Theta Rhythm Power:

The alpha and theta rhythm reflect the cognitive and memory performance of the person. These rhythms are popular among the researchers to do a study in order to analyze the effect of stimuli task on brain performance. Based on the result from paired samples *t*-test, there was no significant difference found in Mozart's music (alpha: p = 0.33 > 0.05, theta: p = 0.26 > 0.05) and white noise (alpha: p = 0.50 > 0.05, theta: p = 0.47 > 0.05) condition relative to the control condition. Based on the mean of alpha and theta rhythm power it shows that the value is decreased during subject listen to the white noise and increase for Mozart's music. It indicates that the activity of the alpha and theta rhythm was less when listen to white noise and higher for Mozart's music. Among the three conditions, the white noise was able to decrease the activity of the brain rhythm. It can remark that the white noise does not disturb the concentration of the subject in memorizing the task. In this study, the power of the theta was higher compared to others since it has relation to the working memory. Theta rhythm represents the deep relaxation, meditation, focus, creativity skills and hypnogogic state. Mostly, people believe that the silence condition is effective for memorizing the task since no others external factors may affect them. However, based on the previous and present study the silence condition is not the best condition for memorizing or study. The people easily to feel boring and sleepy when no sound stimuli expose to them. This situation may distract the performance of people in memorizing the task. The subject will not really focused on the task since they need to overcome the sleepiness and boredom, thus the brain was not effective to process the input information.

Table 3: Mean and Standard Deviation (μV^2/Hz) of Brain Rhythm Power in Control Condition

	Fp1	Fz	F8	T3	T4	Pz	O1	O2	Average
Gamma	4.39(2.26)	2.91(2.61)	3.53(2.41)	5.28(4.00)	3.65(2.91)	3.65(2.47)	3.14(2.56)	3.29(2.23)	3.73(2.68)
Beta	31.72(18.96)	10.24(6.41)	13.49(7.25)	9.06(5.03)	9.10(6.53)	14.07(10.27)	9.75(5.60)	8.15(4.76)	13.20(8.10)
Alpha	162.75(105.56)	24.75(13.35)	36.49(25.36)	14.62(8.12)	14.56(8.53)	23.63(13.99)	15.77(8.90)	14.28(7.74)	38.36(23.94)
Theta	389.13(231.15)	44.89(25.10)	74.23(50.80)	22.98(12.71)	27.74(18.80)	28.13(13.69)	22.95(16.74)	18.96(10.53)	78.63(47.44)

Table 4: Mean and Standard Deviation (μV^2/Hz) of Brain Rhythm Power in Mozart's Music Condition.

	Fp1	Fz	F8	T3	T4	Pz	O1	O2	Average
Gamma	5.51(3.77)	3.56(3.90)	5.82(6.78)	5.17(6.48)	5.77(7.46)	7.28(8.07)	4.13(5.00)	4.04(3.96)	5.16(5.68)
Beta	37.64(21.55)	12.12(7.77)	14.45(10.50)	7.51(5.30)	9.62(9.29)	15.15(12.37)	12.95(14.63)	11.3(8.93)	15.09(11.29)
Alpha	179.07(92.24)	27.48(10.90)	38.56(27.94)	15.33(8.55)	15.04(7.41)	18.78(8.86)	15.87(8.11)	14.66(6.88)	40.60(21.36)
Theta	430.43(241.17)	49.70(21.38)	80.12(56.53)	22.44(10.67)	26.41(12.90)	27.11(13.24)	22.25(11.07)	20.29(10.26)	84.84(47.15)

Table 5: Mean and Standard Deviation (μV2/Hz) of Brain Rhythm Power in White Noise Condition

	Fp1	Fz	F8	T3	T4	Pz	O1	O2	Average
Gamma	4.28(2.30)	3.37(2.43)	3.47(2.70)	4.29(3.36)	2.63(2.62)	4.73(3.93)	3.28(28.4)	3.67(2.34)	3.72(6.01)
Beta	29.27(12.65)	11.04(4.54)	11.66(5.29)	9.77(5.99)	7.27(4.37)	11.18(6.91)	10.58(8.08)	10.09(6.34)	12.61(6.77)
Alpha	147.81(77.27)	29.35(10.43)	31.74(19.17)	16.36(8.30)	18.45(9.31)	21.13(13.27)	14.30(7.60)	15.24(7.58)	36.80(19.12)
Theta	360.24(183.94)	50.26(28.21)	70.25(50.25)	28.32(12.71)	23.76(17.03)	26.53(12.16)	21.4(13.45)	23.59(13.14)	75.54(41.36)

Score of Task Performance:

According to the paired samples *t*-test analysis, the means between Mozart's music and control condition does not show any significant differences ($p = 0.278 > 0.05$). However, there was a significant difference between white noise condition and control condition ($p = 0.025 < 0.05$). The percentage score performance of subject in white noise condition (93.6%) was better compared to control (84.0%) and Mozart's music (90.8%) condition. It indicates that the white noise has enhanced the performance of subjects in memorizing the task. EEG power reflects the number of neurons that discharge synchronously that can be used to measure the capacity or performance of cortical information processing. Among the brain rhythm, it has found that the most influence was alpha and theta since it has higher power at selected channels. Theoretically, the alpha and theta has the functional linking with the cognitive processing and the memory process (B. Geethanjali *et al*., 2012). Based on the previous research, the alpha and theta rhythm characteristic was used as an indicator for determining the effect of task and sound stimuli on brain signal (Wolfgang Klimesch, 1999). In the frontal location (Fp1, Fz, F8), the power of brain rhythm was higher during listen to the Mozart's music while memorizing the task. The frontal lobe is responsible for decision making, attention action and higher cognitive thinking such as planning. The Mozart music is not suitable to be listened while memorizing the visual working memory task since the brain need to work hard. The subject requires much attention in this condition that cause the EEG signal power to increase. However, in white noise condition the EEG signal power was decreasing at Fp1 and F8 location due to the subjects were able to memorize the task with less concentration. It indicates that the white noise does not disturb the subject during memorizing process and make them feel more calm and relaxed compared to Mozart's music.

The sound stimulation is able to increase and decrease the power of the brain rhythm depending on its nature. Relative to the silence condition, the Mozart's music has increased the brain rhythms power and white noise has decreased it. Based on previous and present studies, the Mozart music and white noise can improve the person's memory performance. The result of this study also same as the previous which was the Mozart's music and white noise can improve the subject's ability to memorize visual working memory task compare to silence condition. The interesting findings in this study were the difference in brain rhythm activity were detected when the subject memorized the task in Mozart music and white noise condition. Although both sound gives a positive impact on memory performance but the Mozart's music has increased the power of brain rhythms. It indicates that the brain activity was higher at gamma, beta, alpha and theta frequency. The differences in brain rhythm activity were identified when using different sound stimulation. This difference exists because tone of the sound. The brain need to work hard during listening to Mozart's music compare to white noise in order to process the input information. This situation is not the best for study since more energy required in order to memorize the task. It shows that the white noise is more effective for memorizing the visual working memory task compare to Mozart's music based on the score performance and the effect on brain rhythm power. Generally, the presence of noise during the performance of cognitive tasks involving memory, commonly causes a subjective experience of annoyance, which can lead to a decline in performance (Takahiro Tamesue *et al*., 2012). Noise can be categorized into two groups which are meaningful and meaningless to human memory. Meaningful noise is able to enhance the human cognitive thinking.

It has been a long time ago, humans are trying to understand what memory is, how it works and what factors affected it. Studying on human memory makes people becomes more appreciate to take care of their brain. The performance of memory depends on the health of the brain. Memory can be defined as the ability of us to encode, store, retain and recall information and past experiences in the human brain (Sara B. Kirkweg *et al*., 2013). There are three basic types of memory; sensory memory, short-term memory and long-term memory. Memory is the total sum what we remember that make us able to learn and adapt from previous experiences. As an example, student taken a physic examination he/she need to recall back what have learn before in order to answer the question. The input information will go through into three processes in the human brain. The processes involve are encoding, retention and retrieval. Encoding or registration is the first stage which taken the input information from sensory stimuli, whether through visual, sight, taste, smell or touch. Then, the information will be stored in the memory known as retention process. The store information will be slowly fading with the time. When we recall back the information the retrieval process is involved. Memory can be affected by various factors that cause the forgetting situation, as examples physical state, cognitive factors, emotional factors, environmental factors, task demands and meta-memory. In this present study, the effect of environmental factors (sounds) was investigated on the memory performance in order to determine the effective sound stimulation to hear during the memorizing process based on power of brain signal.

Conclusion:

Mozart's music and white noise are a popular sound stimulus that believes able to enhance the cognitive processing and memory performance. In this present study, this sound stimuli are used to determine the effect on brain rhythm power during memorizing the visual working memory task. Realizes that the importance of determining the best sound to be heard during do intellectual activities, thus this study aim to investigate the relationship between the sound and brain activity. The brain rhythm power has been extracted by using wavelet approach. Listening to the Mozart's music while memorizing the task has increased the power of the alpha, beta, theta and gamma rhythm, whereas the white noise has decreased the EEG signal power relative to the control condition. The higher brain signal power indicates that the brain need to work hard to process the information from the sensory input. Thus, listening to the Mozart's music is not suitable during memorize the task since, it has increased the brain activity. The brain rhythm power increase due to the brain need to filter out the sound come from outside and at the same time need to focus on memorizing task. However, the white noise has a uniform tone which does not disturb the subject of memorizing the task. It makes the subject more focused on the task. Thus, the white noise is more effective to be listen since it able to decrease the stress level of subjects in memorizing the task.

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