BACKGROUND AUDITORY STIMULI EFFECT ON MEMORIZING TASKS PERFORMANCE BASED ON ELECTROENCEPHALOGRAPHY

SYARIFAH NOOR SYAKIYLLA BINTI SAYED DAUD

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Specially dedicated to my beloved *Ma* and *Abah*

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ABSTRACT

Listening to music/sound during study can give positive and negative influence on human cognitive processing. Thus, it has attracted researchers to conduct studies using various types of sound stimuli. Some researchers believe that Mozart music and white noise are able to give positive influence on cognitive performance. However, most of the past studies gave more attention towards spatial task. Very little studies have been made on the effect of Mozart music and white noise towards memorizing task. Besides, the effect of these sounds on task difficulty has also not been studied deeply. Hence, the aim of this study was to investigate the effect of Mozart music and white noise on memory performance with different task difficulty levels in order to propose an effective background stimuli condition for memorization. Experiments have been conducted involving 60 adults that required them to memorize the visual memory task with two difficulty levels; i.e. easy and difficult. Brain signal was recorded during memorization duration using 10-20 electrode placement system of electroencephalography (EEG) machine. EEG is a neurological test for measuring and recording the electrical activity of the brain. The effect of sound stimuli on memory performance was evaluated based on memorization test score and brain activity. The wavelet approach was used in processing the EEG data. Based on the memorizing test score result, the subjects are able to memorize better when listening to white noise (easy: mean = 8.561; difficult: mean = 4.228) compared to Mozart music (easy: mean = 8.070; difficult: mean = 3.632) at different difficulty levels. Listening to auditory background stimuli can influence the electroencephalography pattern and brain activity. The level of attention, thinking, alertness and input information processing increases when listening to white noise which cause the increase of relative gamma and beta power. Thus, in this study, it is found that listening to white noise is far more effective in memorizing process compared to Mozart music.

ABSTRAK

Mendengar muzik/bunyi semasa belajar dapat memberi pengaruh positif dan negatif terhadap pemprosesan kognitif manusia. Berikutan itu, ia telah menarik ramai penyelidik untuk menjalankan kajian dengan menggunakan pelbagai jenis ransangan bunyi. Beberapa penyelidik mempercayai bahawa muzik Mozart dan hingar putih boleh memberi pengaruh positif terhadap pencapaian kognitif. Walaubagaimanapun, kebanyakan kajian lebih memberi tumpuan terhadap tugasan spatial. Kajian kesan muzik Mozart dan hingar putih terhadap tugasan hafalan adalah sangat terhad. Selain dari itu, kesan bunyi ini terhadap kepayahan tugasan juga tidak dikaji secara mendalam. Oleh itu, tujuan kajian ini adalah untuk mengkaji kesan muzik Mozart dan hingar putih terhadap prestasi daya ingatan dengan tahap kepayahan yang berbeza bagi mencadangkan ransangan persekitaran latar-belakang yang berkesan untuk penghafalan. Eksperimen telah dijalankan dengan melibatkan 60 orang golongan dewasa yang memerlukan mereka menghafal tugasan memori visual dengan dua tahap kepayahan; iaitu mudah dan susah. Isyarat otak telah direkodkan ketika menghafal dengan menggunakan mesin elektroensifalografi (EEG) bersistem penempatan elektrod 10-20. EEG adalah ujian neurologi bagi mengukur dan merekodkan aktiviti elektrik otak. Kesan ransangan bunyi terhadap prestasi daya ingatan dinilai berdasarkan markah ujian menghafal dan aktiviti otak. Kaedah gelombang kecil telah digunakan untuk memproses data EEG. Berdasarkan keputusan ujian hafalan, subjek mampu menghafal dengan lebih baik apabila mendengar hingar putih (mudah: purata = 8.561; susah: purata = 4.228) berbanding muzik Mozart (mudah: purata = 8.561; susah: purata = 4.228). Mendengar ransangan bunyi boleh mempengaruhi corak elektroensifalografi dan aktiviti otak. Tahap tumpuan, fikiran, kepekaan dan pemprosesan maklumat meningkat apabila mendengar isyarat hingar putih yang menyebabkan peningkatan kuasa relatif gamma dan beta. Maka, dalam kajian ini didapati bahawa mendengar hingar putih adalah jauh lebih berkesan untuk proses menghafal berbanding muzik Mozart.

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LIST OF SYMBOLS AND ABBREVIATIONS

α	-	Alpha
α_p	-	Absolute alpha power
β_p	-	Absolute beta power
γ_p	-	Absolute gamma power
θ_p	-	Absolute theta power
β	-	Beta
ca^{++}	-	Calcium
Cl^{-}	-	Chlorine
δ	-	Delta
γ	-	Gamma
$\overline{X}$	-	Mean
µV	-	Microvolt
n	-	Number of sample
K^{+}	-	Potassium
S	-	Standard Deviation
Na^{+}	-	Sodium
θ	-	Theta
A	-	Approximation
ADCs	-	Analog-to-digital converters
ADHD	-	Attention deficit/hyperactivity disorder
Ag-AgCl	-	Silver chloride
dB	-	Decibel
db3	-	Daubechies order 3
db4	-	Daubechies order 4
D	-	Detail
C	-	Center
CRA	-	Compound remote associated task

CT	-	Computed Tomography
CV	-	Coefficient of variation
DWT	-	Discrete wavelet transform
EEG	-	Electroencephalography
EMG	-	Electromyography
EOG	-	Electrooculography
ERPs	-	Event-related potentials
F	-	Frontal
fMRI	-	Functional magnetic resonance imaging
HLVT	-	Hopkins verbal learning test
HRV	-	Heart rate variability
Hz	-	Hertz
ICA	-	Independent component analysis
ICU	-	Intensive care unit
IQ	-	Intelligent quotient
L	-	Length
MATLAB	-	Matrix laboratory
MMSE	-	Mini-mental state examination
MRI	-	Magnetic resonance imaging
MSE	-	Mean square error
MSP	-	Measuring psychological stress
O	-	Occipital
P	-	Posterior
PET	-	Positron emission tomography
SPSS	-	Software package for statistical analysis
STD	-	Standard deviation
SWT	-	Stationary wavelet transform
T	-	Temporal
THI	-	Tinnitus handicap inventory
VAS	-	Visual analog scale

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CHAPTER 1

RESEARCH BACKGROUND

1.1 Introduction

Knowledge is an understanding, awareness or information that has been obtained by study or experience by learning, discovering or perceiving, and that is either in a person's mind or possessed by people (Russell, 2013). The knowledge is important and powerful part of life. School, college or university are such of place that people can gain knowledge. Focusing on student life, every day they are learning and expose too much of new knowledge, such as information, facts, descriptions or skills. All of this requires them to have a better and good memory in order to process the input information. As we know, education system enforced the student to undergo test, quiz and examination to identify and evaluate their level of the learning process. Performance of the student in answering the task has depended on their ability to interpret the information and knowledge that they have learned before.

It has been a long time ago, the researcher are always interested to examine the human brain and memory further. Many aspects of research were conducted to discover the brain activity, factors that affect memory as well as its function and how does it work (Bell *et al.*, 2006; Passolunghi and Mammarella, 2012). The human brain is one of the unique and complex organ that consist of billions of neurons. Neurons are responsible for processing and transmitting the information through electrical and chemical signals (Chambers and Jonathan, 2007). The input information will be detected by the sensory organs such as hand, nose, ears and other organs that affecting the sensory neurons. Then, the signal sends to spinal cord and brain. The motor neuron receives the input information from the brain and spinal cord to cause muscle contractions. The contractions affect the granular outputs and interneuron, which connect the neurons to other neurons in the brain. The brain processes the information and sends the output to sensory organ again for action.

The brain can be divided into four regions that are cerebral cortex, cerebellum, diencephalon and brain stem (Sweeney, 2009). The interested brain region in this present study is the cerebral cortex, which has four different lobes that are frontal, parietal, temporal and occipital (Jausovec *et al*., 2006; Lin *et al*., 2014; Zhang *et al*., 2009; Zhu *et al*., 2008). Each of the lobes has different functions in order to process the information. The study of brain and memory have been growing since the past 20 centuries due to introducing of advanced neurological test such as computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI) and electroencephalography (EEG). This modality allowed researchers to examine and discover the brain activity, capture the brain image and interpret the required information about the brain. Among the modalities, the electroencephalography technique is widely used among the researchers due to its non-invasive technique, can record the brain signal in a short time and low cost compares to other techniques (Chambers and Jonathan, 2007).

Generally, the human memory can be categorized into three types that are sensory memory, working memory or short-term memory and long-term memory (Henderson, 2005). The information or stimuli were caught-up by sensory responsiveness and will be stored either in working memory or long-term memory. The human memory, easily to be disturbed by external and internal factors such as interference, storage failure, environmental condition, task difficulty and emotional factors (Henderson, 2005; Cowan, 2008). These factors can lead to losing of information. Discovering the effect of sound on memory performance is an interesting work, thus has attracted some researchers to conduct the study (Boyle and Coltheart, 1996; Fu and Kuan, 2009; Zhang *et al*., 2009). The different style of music/sound give different influence on memory performance as reported by them. In their study, the subject required to memorize the task under three different condition; no music, listening to gentle music and heavy music. They had found that the gentle music able to give positive influence on memory performance compare to the others two conditions. Meanwhile, the study by Zhang *et al.*, 2010 was aim to investigate the effect of music familiarity on memorizing task under different difficulty level. This study used visual working memory task with two difficulty level (easy and difficult) with four different types of background condition (no music, Chinese, English and French). The memorizing test score result revealed that the subject had better performance under no noise/silence condition compare to the others. In this present study, the same task assessment as Zhang *et al.*, 2010 with some modification was used. The number of items that need to be remember is reduce from 15 to 10 items only. However, in this study we preferred to use Mozart music and white noise as auditory background stimuli because limited of study had investigate it effect on memory performance.

Listening to background music/sound during performing cognitive tasks can improve the brain functions, make people relaxed, develop creative thinking and increase the work efficiency (Zhang *et al.*, 2009). There are many pieces of research discovered the effect of background music/sound on various types of cognitive task and human population. Examples of human population that involve in the study are normal adult, elderly, epilepsy patient, attention deficit children, attentive and inattentive children, whereas the task involve are episodic verbal free recall test, visuospatial working memory, verbal memory and oddball task (Perlovsky *et al.*, 2013; Bottiroli *et al.*, 2014; Soderlund *et al.*, 2009; Flodin *et al.*, 2012). The Mozart music and white noise are believed able to give positive influence of memory (Jausovec *et al.*, 2006; Soderlund *et al.*, 2009). Rausher and the team have claimed that listening to Mozart music able to enhance the people's performance for the spatial task (Rauscher, *et al.*, 1995). Starting at that time and up to now this music is still used in the study. White noise is a type of noise that people believed can disrupt the cognitive performance. However, the researchers have found that listening to certain noise such as ambient noise and white noise at a specific intensity are able to improve the cognitive process (Mehta *et al.*, 2012).

The Mozart music is popular among the researcher because of its highly structured organization which has potential to excite the same cortical firing patterns that used for cognitive processing (Konner, 2013). It was considered as a highly structured for three different reasons. First, its harmony has approximately 8-bar phrases that separated by definitive cadence points which is easy to distinguish the differences of each section. Besides, the beats were divided equally at constant tempo. The last reason is it used various types of equipment or voices, but often combined into single. Shaw *et al*., (1985) reported that the effect of music can be represented by Trion Model. This model suggests that the music has the ability to alter the synaptic weights of neurons in specific patterns due to Hebbian learning principles (Konner, 2013). In this principle, the brain regions that involve for learning process was explained. They believe that when listening to Mozart music or any music the neuron firing becomes stronger and each time the new information enter the memories it able to process the information actively and decrease the losing of information.

White noise can be recognized by 'sh' sound. Some of the researchers reported that listening to it during performing the task able to give a positive influence on cognitive processing. The explanation on how the white noise, improves the cognitive processing represented by the stochastic resonance concept (Soderlund *et al*., 2010). The simple example to describe this concept is when the weak signal (e.g. visual stimulus) enters the sensory memory it becomes detectable when white noise is added to the signal (Soderlund *et al*., 2010). The white noise was interacting with the weak stimulus and pushing it or in simple word it gives motivation to people to give more attention on the input information, thus increase the performance. Stochastic resonance improves the touch, auditory, and visual sensory. The previous works showed that the white noise has improved the human performance in verbal task, arithmetic task and the spatial task.

1.2 Problem Statement

During study time, student are engaged with many learning activities such as memorize the formula, facts, definition, structure of the design, reading, and drawing. Some of them are able to recall the required information during the examination, however, some of them are unable to retrieve what they had learned.

Thus, it may affect their examination result. This factor may affect the performance of student to process the information. All of these activities considerably burden the memory. Too much of information that enters the memory can decrease its performance, thus to help the student in improving their memory is by proposing a suitable learning tool, technique and approaches. In this modern technology era, there are many of the new technique and learning tools has been introduced in educational field in order to improve, motivate and encourage student for learning process.

Todays, gamification in education is one of the famous tools that apply for student learning. According to Deterding *et al*., (2011), the gamification can be defined as the use of game design elements in non-game contexts that can be applied in marketing, health, politics, fitness and education. In education field it help the student to get more motivation in study and improve their skills such as problem-solving, collaboration and communication. As we know, the student will be happy when they heard the ‘games’ word. Thus, by introducing the gamification will attract them to learn with joy and happily. Example of gamification application in education are DuoLingo (learn a language while translating the web), Ribbon Hero (epic game that teaches student to use Microsoft office), ClassDojo (turns the class into a game of rewards and instant feedback) and Brainscape (turns confidence based repetition into a game). Actually, the gamification application is not an effective tools to be apply for student since it more to playing compare for learning. The student cannot gain too much of require information from gamification. Thus, other type of approaches should be propose in order to suggest the effective environment for learning process.

The effective study environment is the condition that can give the positive influence on student performance. Listening to the sound/music is another technique that student always prefer in order to give them a motivation and enjoyment during study. According to Soderlund *et al.*, (2010), the human cognitive processing is easy to be disturbed by incompatible environmental stimulation, thus distracts the student attention from required tasks. They had investigated the effect of white noise on inattentive and attentive children on performing episodic verbal free recall test. The children required to take the assessment in two different conditions which are under low-noise (no-noise) and high-noise (white noise at 78 dB of volume intensity) condition. They found that the performance of inattentive children was improved when listened to white noise but not for attentive children. It showed that the inattentive children was easy to be affected by white noise compared to attentive children. Based on their finding, we can see that the human cognitive performance can be influenced by the auditory background stimuli but depends on the human population, types of sound stimuli and cognitive task involved. Based on the Soderlund *et al.*, (2010) findings, we are inspired to discover the effect of environmental factors on memory performance for normal adult population. Knowing from the previous research, Mozart music and white noise are able to give the positive influence on people's performance. Thus, we chose it as auditory background stimuli in this present study.

However, the limitation of the existing study is that most of them focused on the effect of Mozart music or white noise on spatial ability task. The only limited study has been reported on determining the effect of Mozart music and white noise on memorizing ability. Furthermore, up to now only a study by Bottiroli *et al.*, (2014) has determined the effectiveness between the Mozart music and white noise. In their study the effect of Mozart music, Mahler music, white noise and no music condition was examine on the elderly by using tapping declarative memory and processing speed task. The findings has shown that the Mozart music enhanced the elderly performance for tapping declarative memory (episodic and semantic memory task) and processing speed task compare to other three conditions. They state that the reason of Mozart music is more effective compare to others conditions is related to people arousal and mood (Bottiroli *et al.*, 2014). Increasing of positive mood and arousal can improve the people performance. However, in their study they are focusing on the effect of sound stimulation on tapping declarative task and processing speed task only. The argument here is what about the effect of Mozart music and white noise on memorizing task. Does it give same result as their finding?

As been discussed earlier, memorizing is one of the technique that involve during the learning process in order to obtain the knowledge. Thus, the factors that can enhance the memory performance should be investigated. The memorizing task can be categorized into two that are visual memory and verbal memory. In this present study, the assessment task in Zhang *et al*., (2009) study was used. They chose to use the visual memory task that consisted image and number in order to avoid the language effect on subject's performance. In their study, the effect of lyrics on memory performance was investigated. However, in this present study we are aimed to determine the effect of sound harmony and beats by using the Mozart music and white noise as stimuli. The white noise has approximately constant harmony and beats, but the Mozart music has slow, fast, low and high harmony and beat. Besides, most of the previous works interested to use high volume intensity of white noise that actually not suitable for long-term activity such as for study purpose that may affect the human physiological and psychological. Thus, we improved the limitation by using a moderate volume intensity (40-55 dB) of Mozart music and white noise.

Then, focusing on the Zhang *et al*., (2009), Soderlund *et al*., (2010) and Bottiroli *et al*., (2014) works, there has a number of limitations can be found. In Zhang *et al*., (2009) study, they use the auditory background stimuli that have a lyrics. But, they found that the silent condition was more effective in improved the memory. Thus, we can see that the music with lyrics does not give beneficial influence on memory. So, in our study we want to eliminate the effect of music lyrics by using pure sound. Besides, they also used high intensity level of sound volume. High intensity level of sound can cause hearing problem, increase heart rate and blood pressure, thus, in this present study we used medium intensity volume level for playing the Mozart music and white noise. The effect of music on memory performance in Zhang and team study was evaluated based on memorizing test score result only. It is not enough to give brief discussion on how actually the stimuli affect the memory performance and how does it affect the brain. The effect of music on brain activity was not investigated. It will be interesting if we discover the relationship between the positive and negative influence of music towards brain activity.

Meanwhile, for the study by Soderlund *et al*., (2010), the weakness that can be observed are they played high volume of white noise on children. As discussed before, too high of volume not suitable to be used especially on children. Other than that, the effect of task difficulty also does not discover. Then, for the study by Bottiroli *et al*., (2014), they are only determine the effect of white noise and Mozart music on verbal memory task but not on visual memory task. Some of the study reported that the auditory background stimuli give difference influence between visual and verbal memory task (Zhang *et al*., 2009). Besides that, the verbal memory task is not suitable to be used for short time experiment and the language of the words will affect the subject performance.

In summary, the gap of knowledge from previous study are focused on three major criteria that are type of task, volume intensity level of auditory background stimuli and type of measurement. Brief discussion on the limitation of the previous study and contribution in this present study is explain in chapter 2. Therefore, this study selected the subjects among university students and the effect of auditory background stimuli on memory performance is evaluated based on the memorizing test result and brain activity. Findings from this study aims to help the student to choose the most effective and right environmental condition for studying/memorizing process.

1.3 Research Question

a) Do the Mozart music, white noise and task difficulty have different effects on memorizing test score result and electroencephalography pattern?

b) What is the relation between electroencephalography patterns with memorizing performance for visual memory task?

c) Which is more effective between Mozart music and white noise as an auditory background stimuli for memorizing visual memory task?

1.4 Research Objectives

The aims of this study are:

a) To investigate the effect of Mozart music, white noise and task difficulty have on memorizing test score result and electroencephalography pattern.

b) To discover the relation between electroencephalography patterns with memorizing performance for visual memory task.

c) To determine the effective auditory background stimuli on improving the memorizing performance for visual memory task.

1.5 Scope of Study

In the proposed study, the effect of Mozart music and white noise on brain activity and memory are investigated by using electroencephalography modality. The aim is to indicate either Mozart music or white noise is effective in memorizing process. An experiment is conducted in order to obtain the brain signal and task score. The visual working memory task with two difficulty task (i.e. easy and difficult) is uses in this study. The subjects are required to memorize the task in 2 minutes and the brain signal is recorded during this time. The experimental condition are silent (no sound stimulation), listening to the 2 pianos in D4 Major, K 448, and listening to the pure white noise. Subjects were selected among the Universiti Teknologi Malaysia student. Only the subject that pass mini-mental state examination score and healthy condition test are undergo the experiment. The Nihon Kohden (Neurofax 9200) of electroencephalography machine with 10-20 placement system is used for recording the brain signal.

There are four basic stages involve in this study which is:

(i) Data acquisition:

Software use: MATLAB

Collection of the EEG signal and memorizing task score of the subject.

(ii) Data preprocessing:

Software used: MATLAB

a) Selection of EEG channel: The channels are Fp1, Fz, T3, T4 and Pz. Signal Denoising: Filtering the electromyography (EMG) and electrooculography (EOG) artefact in the EEG signal using db3 mother wavelet stationary wavelet transform (SWT) with 5 decomposition level.
b) Signal Decomposition: Decompose the EEG signal to alpha, beta, theta and gamma rhythm using db4 mother wavelet discrete wavelet transform (DWT) with 7 decomposition level.

(iii) Data processing:

Software used: MATLAB

a) Feature extraction: In this stage the time domain and frequency domain of EEG features are extracted. The time domain features such as mean, standard deviation and peak-to-peak amplitude are extracted from EEG voltage. Meanwhile, the frequency domain features such as relative power are extracted from EEG brain rhythm.
b) Normalization of EEG data: The absolute z-score is use for normalize the mean, standard deviation and peak-to-peak amplitude feature. Meanwhile, the brain rhythm power is normalize by dividing the interested rhythm power with the total power. The normalize value represent the relative power.

(iv) Data analysis

Software used: Statistical Package for Social Science (SPSS) and Microsoft Excel

The statistical analysis of signed ranked test is used to determine the significant difference of the memorizing task score between the conditions. Meanwhile, the percentage changes is calculated for each of time domain and frequency domain features in order to determine the percentage increase and decrease of auditory background stimuli relative to control condition.

1.6 Expected Outcome

a) Listening to Mozart music and white noise with memorizing at different level of task difficulty give different influence on the memorizing test score result and electroencephalography pattern.

b) There is a relation between the increases and decreases of relative rhythm power value at Fp1, Fz, T3, T4 and Pz channels on attention level, thinking level, information processing and mood and arousal of subject on memory performance.

c) The white noise is more effective compared to Mozart music as an auditory background stimuli for memorizing visual memory task.

1.7 Thesis Outline

Chapter 1

This chapter introduced the background of the study, research question, research hypothesis, expected outcome and scope of the study.

Chapter 2

This chapter briefly discussed in the background materials of the study. The previous works that use Mozart music and white noise as the auditory background stimuli were discussed. Besides that, the theoretical knowledge of the human brain, working memory and electroencephalography also describes.

Chapter 3

The methodology and design of the research are described deeply in this chapter. The discussion of data acquisition/collection, processing and analysis are found in this chapter. The procedure of the experiment, types of mental task and sound stimuli was introduced.

Chapter 4

This chapter introduce the processing of electroencephalography signal for denoising, decomposing brain rhythm and features extraction purpose. The comparison between denoising of EEG signal using Butterworth bandpass filter and stationary wavelet approach is also discussed in this chapter.

Chapter 5

This chapter was discussed on the result of the research based on two measurement which are memorizing task score result and electroencephalography pattern.

Chapter 6

The finding of this present study was summarized and future works were discussed for improvement.

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