ANALYSIS OF COGNITIVE FLEXIBILITY BY USING EEG IN THE PRESENCE OF BACKGROUND MUSIC

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A project report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Engineering (Hons) Electronic Engineering

Faculty of Engineering and Green Technology
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DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"ANALYSIS OF COGNITIVE FLEXIBILITY BY USING EEG IN THE PRESENCE OF BACKGROUND MUSIC"** was prepared by **NG JIAN TONG** has met the required standard for submission in partial fulfillment of the requirements for the award of Bachelor of Engineering (Hons) Electronic Engineering at Universiti Tunku Abdul Rahman.

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Date : ___________________________

Specially dedicated to

my beloved mother and father

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LIST OF SYMBOLS / ABBREVIATIONS

Pi	the probability of occurrence of each motif in the signal
tie	noise threshold
τ	lag
r	small positive constant
$C_i^m(r)$	probability that any vector $X_m(j)$ is within r of $X_m(i)$
↑	Increased
↓	Decreased
√	Significant
✘	Insignificant
EEG	Electroencephalogram
F	Frontal
T	Temporal
C	Central
P	Parietal
O	Occipital
CPEI	Composite Permutation Entropy Index
ApEn	Approximate Entropy
SampEn	Sample Entropy
SCWT	Stroop Color-Word Test

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CHAPTER 1

INTRODUCTION

1.1 Background

Emotions are referred to as human feelings such as anger, sadness and happiness. In our daily life, emotions play an imperative role as every thought and action controls and dominates through our emotional past experiences. They shape our future responses and prepare our actions to different situations and activities (Ramaprasad, 2013). Thus, it plays an important role in our life. In this study, stress emotion is focused upon as it has proven to be a popular and significant topic in recent years. In modern society, individuals are expected to acquire latest information, competitive skill sets and intrinsic relationship network. Such expectations create high tension environment in life and cause over capacitance of emotional control; thus leads to stress. As reported in a study, overstress in an individual may create somatopsychic abnormalities due to inability to adapt to stressful situations. Each individual has unique stress limit based on life conditions and tolerance (Otsu et al., 2012).

Human brain is known as one of the greatest complex structures in the creation as it acts as the control center of nervous system in a human body. Minor changes in surroundings such as smell, sound and light can be detected and interpreted in the brain before performing an action. After brain interpretation, examples of actions performed are muscle movement and organ regulation in human body (Russell, 2013). The response-action activity of the brain involves the electric field changes through numerous thousand neurons inside the brain. The electrical field transfer can be detected via specific devices to track brain activity changes in electrical potential difference measurement (Kenemans, 2013).

There are several techniques that can be utilized to monitor brain activity. Techniques or sensors such as Magneto-encephalography (MEG), Positron Emission Tomography (PET) and Functional Magnetic Resonance Imaging (fMRI) are a few examples of brain monitoring devices. Yet, these methods are considered costly and technically demanding with distinctive method and equipment for monitoring brain activity respectively. Hence, another technique was proposed as it is more reliable and common to monitor the physiological signals such as Electroencephalogram (EEG). It is reported to be an effective way to identify human stress as it has high temporal resolution with relative simple and inexpensive equipment (Schalk & Mellinger, 2010).

Based on Oxford dictionary, music can be defined as a form of art that creates a composition through the combination of vocal or instrumental sounds. In fact, music helps an individual to perform tasks in a more efficient way. Furthermore, many research studies have showed that background music has its positive impact toward patients with moderate patient condition (Wang, Wen & Liu, 2016). This led to the development of music therapy which acts as a supplement of medicine or medicinal treatment. Yet, it was observed that music therapy impacts different people differently due to their mental conditions, age group and health conditions (Pingle & Bhagwat, 2015). Thus, music will be induced in this study to observe its influence towards stress level of an individual. Hence in this study, the effect of music on the EEG signal of human brain will be studied.

1.2 Problem Statement

In this study, stress is defined as a psychological term that is consists of type of emotions which are invisible to human eye. It can have many causes internal (e.g. some illness) or external (e.g. homework, exam, relationship difficulties). Everything that human being face may cause the pressure that result in the stress level to increase. Impact of stress can be varied depending on tolerance level of an individual. For example, appropriate stress level can motivate human beings to stay focused and alert in the working place. In contrast, if the stress level increases beyond a certain threshold, it may affect the health, mood, productivity and life quality.

Many researches showed that excessive stress can affect the overall health, especially mental illness causing anxiety and depression. These are the effects that are commonly observed in day to day life and which may become worse if not treated quickly and correctly. According to Biswas, (2017), a 21-year-old student of Osmania University committed suicide in Hyderabad on 3 December 2017. It was reported that the student was unable to withstand his examination stress. Other than that, close to 40,000 students committed suicide in India from 2011 to 2015 revealed by National Crime Records Bureau (NCRB). In India, tremendous pressure is faced by the students as competitions are fierce and examination determines their future (HT Brand Studio, 2017). Besides, the World Health Organization (WHO) also reported that over one million people commit suicide every year. In Malaysia, most people commit suicide as they are unable to deal with higher pressure in school and work as reported by Yesuiah, (2017). Therefore, we aim to investigate and analyze the EEG signal under different stress levels and to identify whether the music can be used to reduce the stress.

1.3 Aims and Objectives

1. To pre-process the EEG signal for analyzing data accurately.
2. To investigate and analyze the stress level by using EEG.
3. To identify how the music influences the stress level.
4. To understand the relationship between the beta band and stress as well as the relationship between alpha band and music behavior.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, all basic concepts used in this research will be briefly discussed which include electroencephalogram (EEG), brain rhythm, brain anatomy, nervous system, electrodes positioning and Stroop Color-Word Test. Literature review will be covered in this research to understand the project clearly.

2.2 Electroencephalogram (EEG)

In 1924, Hans Berger, a German physiologist had recorded the first human EEG signal (La Vaque, 1999). Even though it is a traditional technique, the development of reliable computer-assisted EEG-analysis had been improved through technological and scientific advances over the years (Amorim et al., 2017). Nowadays, EEG aid in electrical activity diagnosis of the brain that may detect certain diseases and their symptoms. For different brain activities, the EEG traces will be different. It can differentiate the abnormality of brain activity based on the normal one through signal processing methods (Subha et al., 2010). Basically, EEG signal is described as bioelectric potential produced from millions of neuron links in the human brain and it can be detected from human scalp by using the flat small metal discs (electrodes) via wires. The electrical impulses will be analyzed through the electrodes and the produced signals will be recorded in the computer. The electrical impulses recorded by EEG look like wavy lines with different characteristics. These lines would identify presence or absence of abnormal patterns in the signals which may indicate signs of head injury or other brain disorders (Blocka, 2017).

EEG as a noninvasive test that is painless and extremely safe. The EEG does not produce any harmful secondary effect. However, EEG may cause seizures during the stimulation test for an individual who had experienced a seizure disorder. This is due to the deep breathing or light flashing that might require during the test which can triggered seizures (Vrocher & Lowell, 2005).

2.3 Nervous System and Brain Anatomy

There are two types of cells that make up the entire nervous system; these are known as nerve cells (neurons) and glial cells (neuroglia) (Dartmouth.edu, 2017). Normally, neurons transmit information from one cell to another, while neuroglia aid in the information transmission and help to maintain neuron surrounding. Based on the structure of neuron as shown in Figure 2.1, a neuron consists of a nucleus at its head known as soma and it runs along a path known as axon that is covered by a myelin sheath. It receives the information from dendrite and carries it through axon. According to Nordström and Tängmark, (2013), the electrical signals are generated whenever nerve cells communicate with each other. As the neuron undergoes certain concentration changes of potassium (K+) ions, sodium (Na+) ions and chloride (Cl-) ions, an electrical signal is generated. By doing so, it allows the nerve cell to transport the electrical charge via long axon fiber. In addition, the myelin sheath is actually a neuroglia. The refractory period allows the electrical signal travel in one direction only (Nordström & Tängmark, 2013). Hence, the signal can then be transferred from one end to another end through synapses.

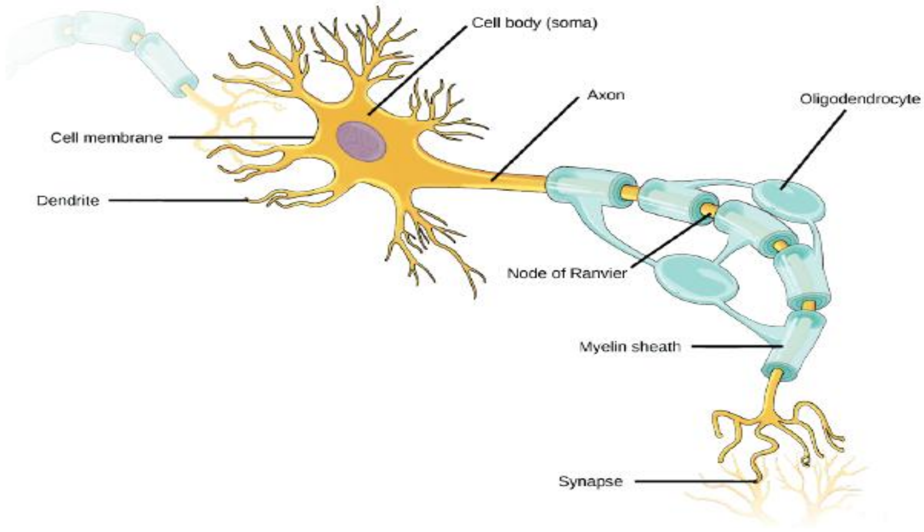


Figure 2.1: Nerve Cell Structure (Nordström & Tängmark, 2013)

As mentioned previously, the most significant and complex organ in human body is the brain. The brain allows human being to sense, smell, think and move. It allows humans to respond properly when a stimulus is received from environment. The human brain is co-divided into three main structures which are cerebrum, cerebellum and brainstem.

Firstly, cerebrum is the biggest region of the brain that deals with major brain function like action and thought. The cerebrum is the cerebral hemisphere or cerebral cortex which can be divided into two parts namely right hemisphere and left hemisphere. The right hemisphere corresponds with verbal processes and the information from left side of the body whereas the left hemisphere is involved with the nonverbal processes and right side of the body (Northeastern.edu, 2017; General Psychology, 2017). Cerebral cortex is divided into four different lobes divided known as frontal lobe, temporal lobe, parietal lobe and the occipital lobe (Damasio, 2005). The general function of each lobe is described below and their visual representations are given in Figure 2.2.

- Frontal lobe
  - It is located at the front region of the brain and manages personality, feeling, high level cognition, body movement, speech, writing and self-awareness.

- Temporal lobe
  - It is found at the bottom of brain. It aids in the language, sound and memory formation as also sequence and organization.
- Parietal lobe
  - It is located behind frontal lobe and above temporal lobes. It controls auditory, vision, sensory information, memory and language signal interpretation
- Occipital lobe
  - It is placed behind the parietal and temporal lobes at the back region of brain. It is involved in visual stimuli and information interpretation or vision.

Secondly, another brain structure is cerebellum which is the smaller part of the brain compared with cerebrum. It is found at the top of the brainstem and below the cerebrum. It deals with the movement regulation, posture control and balancing (Northeastern.edu, 2017; General Psychology, 2017).

The smallest brain structure is brainstem which links both cerebrum and cerebellum to the spinal cord in order to form a pathway for signal transmission. There are three regions consisting in the brainstem which including midbrain, pons and medulla. All of them help in certain basic body functions such as breathing, heartbeat, blood pressure, control of sleep cycles and the body movement (Northeastern.edu, 2017; General Psychology, 2017).

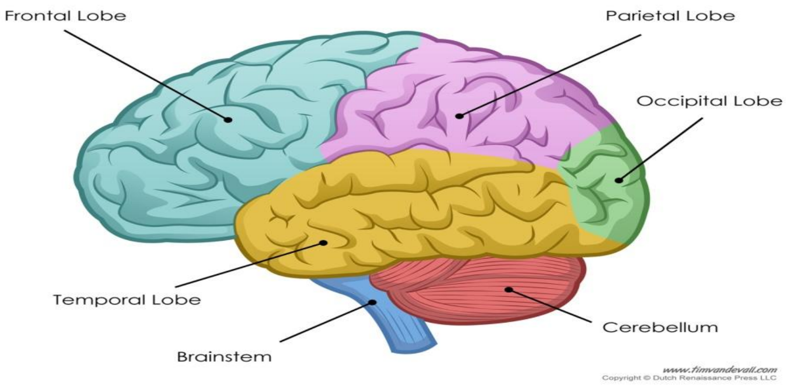


Figure 2.2: Brain Anatomy (Human Anatomy Structure, 2017)

2.4 Brain Wave / Rhythm / EEG Signal

The brain wave can be defined based on its uses. Hsu, (2017) stated that numerous neurons (brain cells) are required to work together in order for human brain cells to communicate with each other. Any behavior or thought that was activated from brain cells is generated from the action potential as the nerve impulses transmitted from one neuron to another and this action potential is normally known as electrical signal itself. Whenever these signals are recorded through EEG, it can be observed on the computer screen as waveforms of varying amplitude and frequency (sinusoidal) typically measured in microvolts (Teplan, 2002). The EEG waveforms are also known as brain waves or brain rhythms which are classified based on their amplitudes, shapes, frequencies and the location of electrode on the of scalp (Sucholeiki, 2012). Generally, humans consist of five different types of brain waves such as gamma wave, beta wave, alpha wave, theta wave and also delta wave (Trivedi & Thakker, 2016). Each wave is categorized in terms of frequency (Hertz) which can be divided into different bandwidths. They can also be further classified as low, moderate and fast waves.

Brief descriptions about the information of distinct brain waves are given as below:

- Gamma Waves
  - There is no "gamma state" in mind, they always act as a "supporter" waves. They are mostly present in EEG signal whenever the subject is awake.
  - They are linked to idea formation, thinking, learning and memory processing.
  - They are not present during deep sleep when anesthesia is induced, yet it appears back during the wakeful state.
  - They normally result in high level of intelligence and self-control.
- Beta Waves
  - They are for found during the 'fight flight response' in human.
  - They are present when the individual is in a situation which requires problem solving, decision making, conscious thought and external effect.
  - They help to improve logical thinking and concentration.
  - There are three different categories of beta waves:

  - Low beta waves (14 Hz – 17 Hz): waves that present when someone is concentrating in meditation.
  - Midrange beta waves (17 Hz – 24 Hz): waves that would be activated when an individual is figuring something out.
  - High beta waves (25 Hz – 30 Hz): waves produced during more complex thought, higher anxiety, worry, stress and excitement.

- Alpha Waves
  - These waves appear when individuals are relax but in awake state (closed to low beta waves)
  - They help to calm down, alertness and mental coordination or promote deep relaxation sense.
- Theta Waves
  - These often appear during daydreaming and sleeping.
  - They help to enhance our intuition, conscious awareness an also creativity.
- Delta Waves
  - They are associated with the deepest level of meditation, relaxation or sleep and involved in unconscious bodily function.
  - They will improve healing and regeneration of human body.

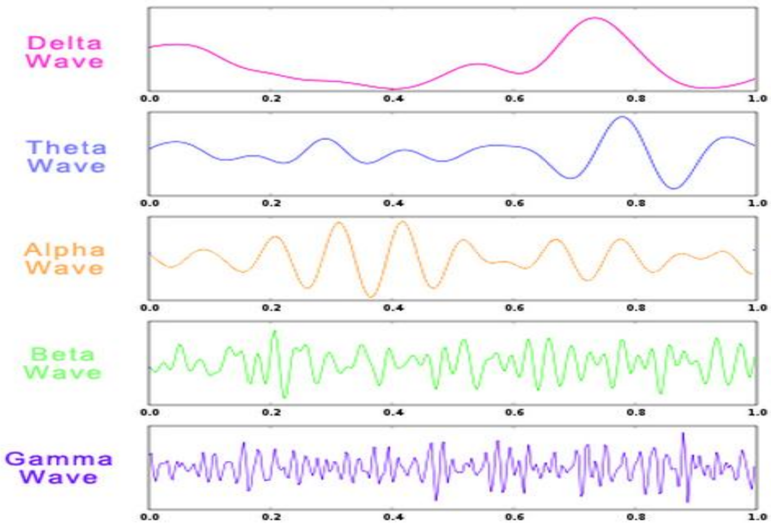


Figure 2.3: Brain Waves (Ecodercrypt, 2013)

Table 2.1: Details of Brain Waves – Summary (Scientific American, 2017; Warner, 2013)

Band	Frequency (Hz)	Associated with	Conditions (Example)
Gamma	31 – 100	- Focused attention - Process information from other areas of brain	-
Beta	14 – 30	- Thinking state - Intellectual activity - Focused sustained concentration	A person who in active conservation.
Alpha	8 – 13	- Relaxation state - Peacefulness - Alertness	A person who has finished a task and rest on a chair.
Theta	4 – 7	- Mental inefficiency	A person who discovers that he can't recalls the food that he has ate just now while he is eating.
Delta	< 4	- Deep dreamless sleep	A person who reads a book for a few minutes before sleep.

Based on above descriptions, the beta wave is the most relevant band that can be used to indicate the stress level of an individual in this study. It can be noticed that an individual who suffers with higher stress level will produce high beta band whereas low level of stress create lower beta band. Moreover, it can also be observed through the alpha band which has opposite function than beta band. Thus, these two bands are the main waves that will be used to identify the stress level in the recorded EEG signals.

2.5 Electrode Positioning

An internationally recognized method to describe the electrode location on the scalp since 1950s is known as 10/20 system or International 10/20 system (Trans Cranial Technologies Ltd, 2012). It is based on the relationship between the electrode location and the cerebral cortex underlying region. The names of the system numbers - “10” and “20” are actually referred to as two adjacent electrode’s distances which are either 10% or 20% (Trans Cranial Technologies Ltd, 2012). According to Seeck et al., (2017), the electrode locations will be identified through the letters and numbers (odd and even) which are used to indicate those underlying regions (Table 2.2) and hemispheres respectively. The even numbers are located on the right hemisphere while odd numbers are located on the left hemisphere (Seeck et al., 2017). The lowercase ‘z’ or “zero” referred to electrodes annotated on the anterior-posterior midline. There are only four lobes present in our brain. Thus, the term “C” is used as a vertex mark only when the central coronal plane is measured from the left pre-auricular point to right pre-auricular point.

Based on Figure 2.4, the lateral view (Figure 2.4-A) of skull shows the measurement method from nasion to inion. As mentioned above, the distance from nasion to inion is indicated in the percentages of 10% and 20%. It is notable that the measurement between front and back starts from nasion through the vertex “C” to inion. The Fp and O electrodes are located 10% away from nasion and inion respectively whereas the rest electrodes are 20% separated from each other by considering distance as total 100% (Klem et al., 1999). This case is similar for the distance which shows in Figure 2.4-B from left to right auricular point.

In recent years, an extended new standard of 10/20 system has been introduced known as 10/10 system (see figure 2.5), in which the gaps between adjacent 10/ 20 sites defined additional positions that covered 20 % of the circumference of the head (Kenemans, 2013). However, the original standard system will still be used in this study through Emotiv EPOC headset which will be covered in next chapter. As the headset used in this study is based on the 10/20 standard which is easy to use.

Table 2.2: Relationship between Electrodes (Letters) and Brain Lobes

Electrode (Letters)	Brain Lobe/ Brian area
F	Frontal
T	Temporal
C	"Central"
P	Parietal
O	Occipital

Note: "Central" is vertex mark not brain area

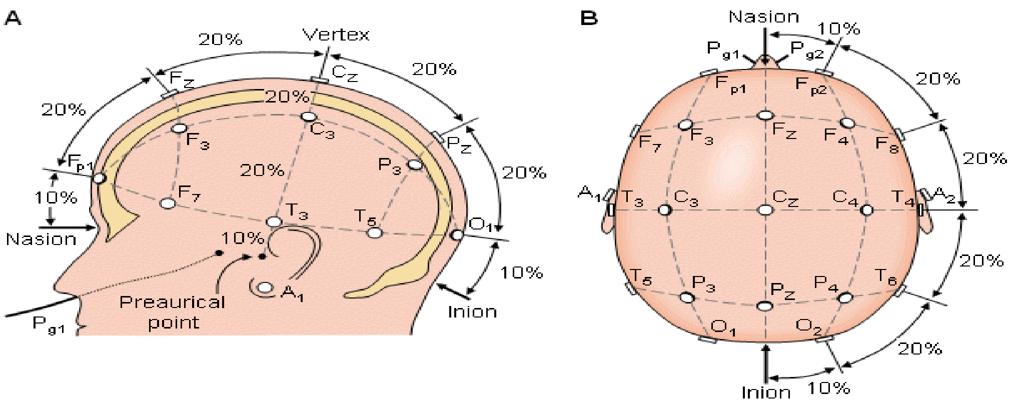


Figure 2.4: The Electrode Measurement Method in (A) Lateral View and (B) Top View (Malmivuo & Plonsey, 1995)

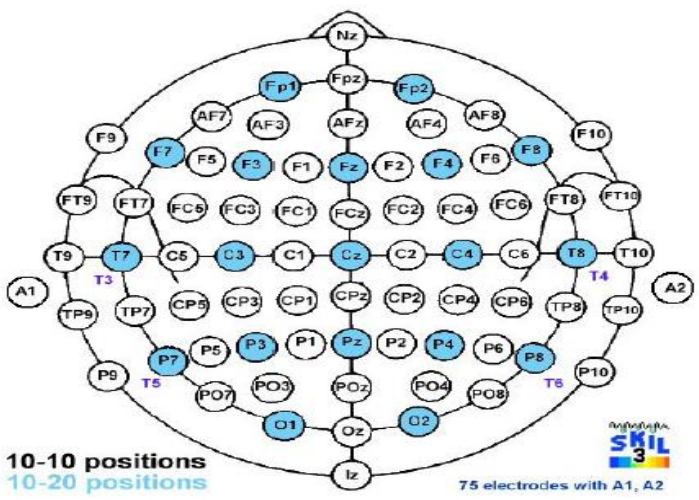


Figure 2.5: The 10/10 and 10/20 Systems for Electrode Placement (Kenemans, 2013)

2.6 Stroop Color-Word Test (SCWT)

The Stroop Color-Word Test (SCWT) is the oldest and common test used in psycho-physiological field since the initial work done by Stroop, (1935). Typically, it is used for investigative response inhibition and executive functions (Schiehser & Bondi, 2009). SCWT consists of several versions and some versions have been translated to other languages for the wider population coverage. In the standard form of SCWT, there are three different formats that are commonly used in experiments (Table 2.3).

Table 2.3: Standard Form of SCWT

Format	Remarks
1 – Figure 2.6	Read the words painted with ink patches. (e.g. word reading)
2 – Figure 2.7 (Congruent)	Name the colors painted on the words that are similar to the names of colors (e.g. color naming)
3 – Figure 2.8 (Incongruent)	Name the colors painted on the words that are different to the names of colors-words. (e.g. color naming)

Other modified versions of SCWT also follow the same format, yet one or more dimensions may be varied such as the presentation formats, color displays (e.g. symbols, shapes or dots), number of colors and trails length (Schiehser & Bondi, 2010). In this study, the congruent and incongruent formats will be used in which an individual is required to press the color representation key in keyboard to response the color instead of word. In general, it is based on the observation whether an individual can read the word faster after identifying the word and name of colors (Golden & Freshwater, 1978). The longer response time that an individual requires to perform the test is normally known as the interference or Stroop effect (Lemercier et al., 2017). Since the SCWT corresponds with the cognitive performance which is influenced by the stress, thus the time required for more stressful person will be longer as compared with less stressful person. In other words, the response times will be varied and will indicate the level of stress of an individual.

Figure 2.6: (a) Format 1: Word Reading, (b) Format 2- Congruent Image: Color Naming, (c) Format 3 - Incongruent Image: Color Naming (Jesús Gil Hernández, 2014)

2.7 Previous Studies and Related Works

Kalas and Momin, (2016) concluded that the EEG signal can be used for stress detection. In their paper, the EEG data was collected from 10 subjects. The EEG data was analyzed into two ways. Stress indices and feature extraction which used for threshold value extraction and dataset redundancy reduction, respectively (Kalas & Momin, 2016). Besides, Vanitha and Krishnan, (2016) also conducted a similar experiment for detecting stress level using EEG signal. They included six healthy subjects in the experiment and the EEG signals were collected through Emotiv EPOC headset. In their experiment, they were given some varied difficulty level and mathematical questions to solve in a specific time period. The whole procedure lasted 20 minutes where the first and last three minutes were relaxation period and 14 minutes in between were divided into seven minutes of low and seven minutes of high level difficulty. The non-stationary EEG signal was then extracted through Hilbert Huang Transform (HHT) based on the relevant features in time frequency domain. By doing so, the hidden information in the signal can be investigated. After that, the feature result from HHT was used for classification. The accuracy of classification was 89.07% (Vanitha & Krishnan, 2016). Thus, the result has showed that the EEG has the feasibility to detect the stress.

Hou et al., (2015), conducted an experiment where data was collected from nine mentally healthy subjects; in the range age of 21 to 28 years. In their study, the SCWT was applied to induce distinct stress levels in different subjects. It consists of four sections which are resting, congruent, incongruent 1 and incongruent 2. Each section was about three minutes long and the EEG data was collected all the time. For every section of tests, subjects were required to rate out from 1 to 9 in the questionnaire as stress level representation. Based on the questionnaire, it was found that subjects' stress level was divided into three groups: 2-level, 3-level and 4-level. Besides that, three features were extracted from the collected data which were power feature (extract power band – theta, alpha and beta), fractal dimension (extract and measure the complexity and irregularity of the signal) and statistical (measure mean, standard deviation and so on) (Hou et al., 2015).

Another study was carried out by Jun and Smitha, (2016) in order to investigate the brain wave's pattern when the mental stress was induced. 10 participants from age group 20 to 35 years were involved in the experiment. In this study, two major tests of SCWT and mental arithmetic test were used to indicate the stress level. There were two stages in the experiment which were 'training phase' and 'testing phase'. The training phase was divided into three sections where three minutes resting section, three minutes SCWT with 20 seconds rest time for second section and three minutes mental test with 20 seconds rest time for the last section. Besides, ten trails were included in the testing phase where each trail was 30 seconds. In this period, the resting stage, SCWT and mental test were played randomly. After that, the experiment followed with survey and 20 second rest time. The band power feature is used to extract band power value of high (beta) and low frequency components (alpha and theta) and SVM is used as classifier. After classification, it was noticed that the alpha band power was higher than power of θ and β band during resting section. It was also found that the beta band power was relatively much higher than theta and alpha in the section of SCWT and mental arithmetic test. As the result, it had obtained 88% and 96% accuracy for SCWT and mental arithmetic test respectively in the stress level detection which is higher than the one reported in Hou et al., (2015) (Jun & Smitha, 2016).

Based on the study mentioned above, it can be noticed that various ways of analysis and classification of EEG data had been used. In our study, we plan to use power spectral analysis (power feature) and time series analysis (composite permutation entropy index and sample entropy) to extract the features instead of using such HHT, fractal dimension, statistical which will be explained in detail in next chapter. The table below briefly discussed the methods reported in literature to analyze stress level.

Table 2.4: Summary of Literature Review

Authors	**Input Signal**	**Feature extraction method**	**Classifier (Processing Technique)**
Vanitha, L and Suresh, G.R. (2013)	Electrocardiogram (ECG)	i) Time domain analysis -Heart Rate Variability (HRV): useful for evaluating function of cardiac autonomic. ii) Frequency domain analysis -Calculate the power spectral density of HRV.	-Self-Organizing MAP (SOP) -Support Vector Machine (SVM) ➔Accuracy = 91%

Xu, Q., Nwe, T.L. and Guan, C.,Guan (2015)	**Electroencephalogram (EEG)** → (Band used : **Delta, Theta, Alpha and Beta**) -Electrocardiogram (ECG) -Electromyography (EMG) -Galvanic Skin Response (GSR)	- Power spectral for EEG - HRV for ECG -mean and standard deviation for GSR and EMG	-Clustering-based analysis Sensitivity analysis
Munla, N., Khalil, M., Shahin, A. and Mourad, A (2015)	Electrocardiogram (ECG)	i)Time domain analysis -HRV ii)frequency domain analysis -Lomb periodogram iii)Time-frequency domain analysis -Wavelet and STFT iv)non-linear analysis --Sample Entropy ,DFA-α1and DFA-α2;detrended fluctuation analysis (dfa)	-K Nearest Neighbor (KNN) -radial basis function (RBF) -Support Vector Machine (SVM).
Setz, C., Arnrich, B., Schumm, J., La Marca, R., Tröster, G. and Ehlert, U (2010)	Electrodermal activity (EDA)	Using wrapper approach to select the feature. (No Specified)	-Linear discriminant analysis (LDA) -SVM -Nearest class center (NCC) algorithm.

Rani, P., Sarkar, N. and Adams, J (2007)	-Electrocardiogram (ECG) -Electromyography (EMG) -Electrodermal activity (EDA) -Temperature	Anxiety index	-Fuzzy logic -Regression three
Reanaree, P., Tananchana, P., Narongwongwathana, W. and Pintavirooj, C (2016)	**Electroencephalogram (EEG)** → (Band used: **Alpha**) -heart rate	"Presented algorithm condition for stress detection" (No specified)	-(No specified)

Furthermore, since EEG is one of the signal-based collection techniques, there are numerous ways to collect signals. In this study, there are different types of signal based collection techniques and table below has summarized those analysis methods which contain EEG features from previous works.

Table 2.5: Summary of Methods Used for Other Applications from Previous Studies

Authors	EEG Feature Used & Purpose
Acharya, U.R., Fujita, H., Sudarshan, V.K., Bhat, S. and Koh, J.E (2015)	Topic related: Epilepsy diagnosis by using entropy. Time Series Analysis: i)Approximate Entropy (ApEn) ⇨ to appraise the signal variation instability ii) Sample Entropy (SampEn) ⇨ to scale the signal regularity iii) Spectral Entropy (SEN) ⇨ to evaluate entropy using amplitude of power spectrum iv) Permutation Entropy (PE) ⇨ to measure the complexity v) Wavelet Entropy (WE) ⇨ to measure the energy in different frequency bands
Mumtaz, W., Xia, L., Malik, A.S. and Yasin, M.A.M (2013)	Topic related: Classified the environment of 2D and 3D physiological conditions Time Series Analysis: i)Sample Entropy (SampEn) ii) Approximate Entropy (PE) iii) Composite Permutation Entropy Index (CPEI) ⇨ Advanced of PE, to reflect the time series complexity iv) Fractal Dimension ⇨ Consider the irregularity and complexity v) Hurst Component

	⇨ To appraise the properties of correlation and self-similarity vi) Hjorth Complexity and mobility ⇨ To evaluate set of parameters: activity, mobility and complexity of EEG signal.
Ahmad, R.F., Malik, A.S., Amin, H.U., Kamel, N., Qayyum, A. and Reza, F (2015)	Related topic: Classified the active and resting state using nonlinear feature Time Series Analysis: i)Sample Entropy (SampEn) ii) Approximate Entropy (PE) iii) Composite Permutation Entropy Index (CPEI)
Khairuddin, H.R., Malik, A.S., Mumtaz, W., Kamel, N. and Xia, L (2013)	Related topic: Analyzed the regularity of EEG signal in adult while playing 2D and 3D game Time Series Analysis: i) Hjorth Parameter ii) Composite Permutation Entropy Index (CPEI)
Ergen, M., Saban, S., Kirmizi-Alsan, E., Uslu, A., Keskin-Ergen, Y. and Demiralp, T (2014)	Investigate the oscillation of event-related which jointed with Stroop Test. Time Frequency Analysis: -Wavelet Transform (No specified)

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the project activities and flow is discussed. The equipments or tools that required are given. During the experiment, the EEG data were collected by using EEG device through the software known as Emotiv Software Development kit. Next, the pre-processing for EEG data was done through EEGLAB in order to remove artifacts. In the end, the new data was analyzed by using MATLAB which will be explained further in this chapter. Based on Figure 3.1, the visual representation of basic project flowchart is given.

3.2 Equipments and Tools

3.2.1 Hardware

i. Emotiv EPOC+ headset kit
   - Headset assembly with rechargeable battery, USB dongle, Hydration sensor pack (16 sensor units), Saline solution, Battery or USB charger

ii. Laptop x 2

iii. Earphone x1

3.2.2 Software

i. MATLAB

ii. EEGLAB

iii. Minitab 17

iv. Microsoft Excel

v. EmotivPRO Software

3.3 Procedure of Data Acquisition and Experiment Design

Before conducting the experiment, all the subjects were required to fill in the consent form together with the perceived stress scale (PSS) and music-stress questionnaires. After that, the subjects were just prepared for data acquisition.

3.3.1 Consent Form

Consent form (see **Appendix A**) is a form that was provided for potential research subjects in order to obtain their agreement to participate in the research study. It is a form that is required to be signed by all the subjects before conducting the experiment. In the form, it provided sufficient information about the experiment procedure, purpose and precaution that was required to make aware by the subjects. Based on the above explanation, the rest of the procedures will be continued once the subjects made an agreement and signed the consent form.

3.3.2 Perceived Stress Scale (PSS-14) and Music-Stress Questionnaires

In this study, Perceived Stress Scale (PSS-14) is used to investigate the stress level. It was originally developed in 1983 and is a psychology and stress assessment instrument to measure the stress perception. According to Cohen et al. (1994), it is a measure of the degree to which situations in one's life are appraised as stressful. In the PSS questionnaire (see **Appendix B**), the questions are generally easy to understand, in which thoughts and feeling were questioned during the last month. For each question, the response alternatives are simple to grasp through the appropriate indicated scale number. By doing so, the higher the score obtained from an individual, the greater the individual is vulnerable to stress.

Other than that, Music-Stress Questionnaire also used in this study and shown in **Appendix C**. Same as PSS, the questions are straight forward and the response alternatives are simple. It asks about individual's preferences about music as well as some related questions toward stress in life. Once both questionnaires are completed and the scores are finished computed for each subject, it will be used for comparison with the feature obtained from the EEG signal to have accurate analysis.

3.3.3 EEG Data Acquisition

There are three main items that are required in this section which include Emotiv EPOC+ Headset, EmotivPRO Software and laptop. In the beginning, all the subjects were required to wear the headset and check for the electrode condition before start of experiment. However, it consists of number of steps to be set up first before wearing the headset which will be covered in the next section. After that, the experiment starts and the EEG data signal will be recorded through the laptop by using Emotiv EPOC+ Headset. Figure 3.2 shows the basic process of data acquisition.

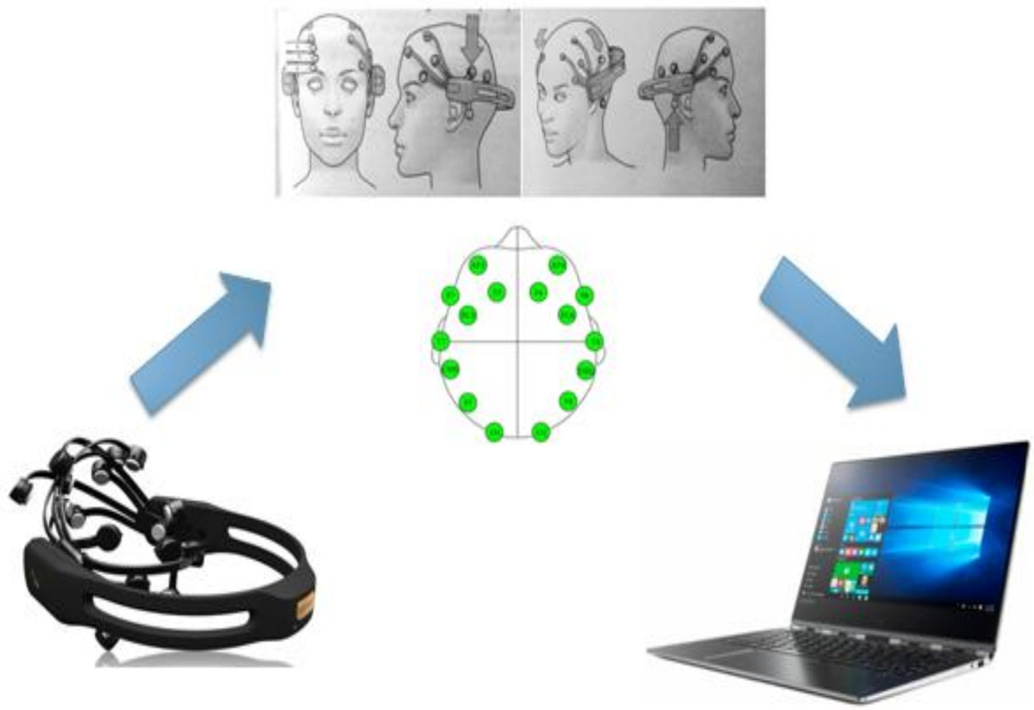


Figure 3.2: Basic Process of Data Acquisition

3.4 EEG Data Pre-processing (remove artifacts)

In terms of signal processing, there are always consist of unwanted signals that are represented as noise. There are known as artifact. Various types of artifact are coming from distinct sources that either internally or externally. Artifact from internal sources are caused by physiological activities of the subject which include body movement, exhale and inhale cycle (respiration), cardiac cycle, blinking of eyes and etc. In addition, cable movement, interference of environment and loose of electrode due to the environment and equipment effects are considered as the external source of artifacts (Islam, Rastegarnia & Yang, 2016; Bhattacharyya et al., 2013). Since artifacts are referred as unwanted signals, they are required to be removed from the recorded data in order to obtain more accurate input signal for further analysis. In this study, the pre-processing of the EEG data is done via EEGLAB. By doing so, all artifacts will be removed regardless of it sources. In order to remove the artifacts, standard procedures and steps of using the EEGLAB are shown in **Appendix G**.

3.5 Cost Analysis and Project's Sustainability

A cost analysis can be defined as a detailed outline or procedure for estimating all the costs involved in the project. It takes both quantitative and qualitative factors into account for analysis of the value for money for a project. By doing so, it can be compared alternatives and prepared budget in order to achieve more efficient work. In this study, several equipments and software are used in order to obtain accurate analysis result. Table 3.1 shows the cost analysis of the hardware and software that are used in this project.

Table 3.1: Cost Analysis

Hardware/ Software	Market Price	Cost Spent
Emotiv EPOC+ headset kit	$ 799.00	*Free (Sponsored by supervisor)
Laptop x2	RM 1500.00 – RM 2000.00	*Free (Own laptop)
Earphone	RM 20.00 – RM 50.00	*Free (Own earphone)
MATLAB	$ 940 – $ 2350	*Free
EEGLAB	-	*Free
Emotiv+ Software	$ 99.00	$ 99.00
Minitab 17	$ 30 - $ 300	*Free
Total Cost Spent		**$99.00 ≈ RM 400.00 (Exact RM 393.89)**

Besides, project's sustainability is a systematic concept which related about balancing of economical, social and environmental interest. By considering the sustainability of project, it can actually reduce the negative impact toward the technology worldwide. However, for this project, sustainability is not taken into account during the project's design as there is not any impact on environment in this study.

3.7 Project Management

Table 3.2: Gantt Chart of FYP I

Details/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Project Proposal / Title Selection	■													
Literature Review and Research Work		■	■	■	■	■	■	■	■	■	■	■		
Introduction of the Project (Report)				■	■	■								
Methodology of the Project (Report)						■	■	■	■					
Feature extraction and selection						■	■	■	■	■	■			
Future direction										■	■	■		
Progress Report Submission												■		
Oral Presentation													■	

Table 3.3: Gantt Chart of FYP II

Details/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Data Recollection	■	■												
Analysis of data: Feature extraction and selection		■	■	■	■	■	■	■						
Improvement				■	■	■	■	■	■	■				
Result and Discussion						■	■	■	■	■	■			
Conclusion and Recommendation								■	■	■	■			
Progress Report Submission									■	■	■			
Final Report Submission												■		
Poster and Oral Presentation													■	■

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter, the results of the project will be discussed. The results of power analysis which includes beta power and alpha power will be analyzed. The behavioral data analysis will also be discussed in this chapter which includes the average response time and test accuracy for the Stroop tasks. The parameters such as CPEI, ApEn and SampEn obtained from the time series analysis of EEG signal will also be interpreted in this chapter. All parameters mentioned above are investigated and the relationship with each other is analyzed in detail.

4.2 Perceived Stress Questionnaire - 14 (PSS-14)

PSS-14 determines subjects' thoughts and feelings in relation to how uncontrollable and unpredictable their lives in the last month. There are 14 questions with different levels of score which include seven positive items out of 14. These positive items describe the positive feelings, in which the score must be reversed for accurate computation. Table 4.1 presents the different score levels based on different type of items. Since the largest score for each item is 4, the maximum score range for the PSS-14 questionnaire is from 0 to 56. Based on the range, the stress level of each subject can be identified and it can be classified into three distinct stress groups: low, moderate and high as shown in Table 4.2.

Table 4.1: Score Level in Different Type of PSS-14 Items

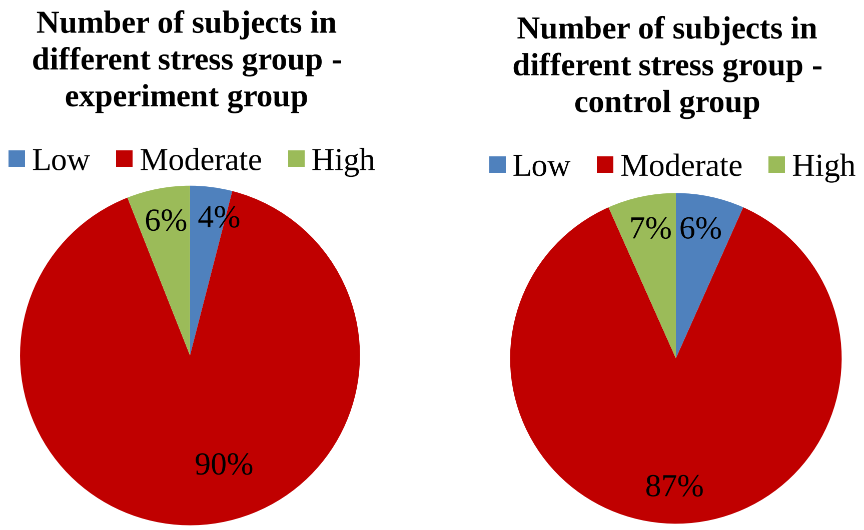
Scores (negative items)	Scores (positive items)	"feeling"
0	4	Never
1	3	Almost Never
2	2	Sometimes
3	1	Fairy often
4	0	Very often

Table 4.2: Scores Range for Different Stress Groups

Scores ranging	Stress group
0 - 18	Low stress group
19 - 37	Moderate stress group
38 - 56	High stress group

Figure 4.1, it shown number of subject in different stress groups. It is observed that majority of the subjects belong to the moderate stress group (90 % in Figure 4.1 (a)). In other words, 45 subjects out of 50 are in the moderate stress group. Only small percentage belong to low and high stress group which is indicated as 4 % (2 subjects) and 6 % (3 subjects) respectively

Figure 4.1 (b), the control group exhibits similar behavior as the experiment group. There are 87 % 13 subjects in moderate group and one each in low and high stress group (13 % combined). According to PSS-14 questionnaire and the result above, the stress level faced by the subjects can be categorized into low, moderate or high level.



(a) (b)

Figure 4.1: Number of Subjects in Different Stress Groups – (a) Experiment Group (total 50 subjects) (b) Control Group (total 15 subjects)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this research, the EEG signal processing methods are used to analyze the cognitive flexibility via Stroop test on different stress groups with and without music. The stress level of the subjects was calculated by using the PSS-14 questionnaire and the Stroop test experiment was designed to act as stressor to evaluate subjects' stress. Based on the experiment, the effect of music towards different stress groups and tasks was identified and observed. In order to analyze the EEG signal, several features were extracted; e.g. power (beta and alpha band power) and time series features (Composite Permutation Entropy Index, Approximate and Sample Entropies). With these features, the changes in the power and complexity level of EEG time series were identified.

For congruent task with no music induced, the response time and task accuracy performance increased from low to high stress group. Based on the overall result, all the subjects responded faster and obtained more accurate result in this stage. Besides, higher average beta power and lower average alpha power were obtained. The average CPEI, ApEn and SampEn values also showed the same result as beta power, in which all the values were high as compared with baseline. When music was induced in the congruent task, there was no significant change of the response time and accuracy performance among all stress groups. However, the average beta power decreased and alpha power increased as compared to no music situation. Similar to the time series features, all average parameter values increased when music was presented.

For incongruent task in no music condition, higher stress group required more response time. However, the accuracy results showed no significant changes in different stress groups. The overall result indicated that the longest time and lowest accuracy obtained as compared to other tasks. The highest mean beta power was present in this task and the task showed low mean alpha power than congruent task. CPEI, ApEn and SampEn results also showed the higher value in this task. In music environment, the response time taken by moderate and high stress groups had decreased but no significant effect of music in low stress group. For accuracy result, it showed no significant difference among all groups. The average beta power decreased whereas the average alpha power increased similar to the congruent task with music condition. CPEI, ApEn and SampEn indicated that the complexity and irregularity levels were increased as compare to the task without music induced.

For the mix task without music presented, the response time result showed similar trend as congruent and incongruent tasks, in which the higher stress group takes longer time to respond than lower stress groups. The accuracy result showed no significant differences among all stress groups in incongruent task. According to the beta results, the average beta power was higher than congruent task and lower than incongruent task. Unlike the beta power, the result showed for alpha power obtained the lowest average value as compare to others. The CPEI and SampEn results showed the same approach as beta power, these values were higher than congruent but lower than incongruent task, as expected. ApEn showed the same observation as alpha power result in no music condition. As music was induced to mix task, the response time decreased but no significant effect of music on accuracy result for all stress groups. As compared to the overall result, it showed that music induced had improved the response speed and accuracy performance. The average beta power decreased, average alpha power increased as compared to no music condition. Similar to the congruent and incongruent tasks, all value of parameters was also increased when music was introduced.

In low stress group, the overall results showed that there were no significant effects of music. In moderate stress group, the results of response time and accuracy depended on the task difficulty level, where more difficult task resulted in longer response time with less accuracy and vice versa. The beta and alpha powers in moderate stress group were higher than low stress group but lower than high stress group. Same result was obtained for the CPEI, ApEn and SampEn. When music was induced, the overall response time, accuracy, CPEI, ApEn and SampEn results were increased. Yet, the average beta power had decreased with no significant change in average alpha power. In high stress group, the overall results and observations were equal to moderate stress group. The only different was the average alpha power had increased when music induced where moderate stress group does not follow this pattern.

Analysis of different brain lobes show varied pattern for both music and without music conditions; as it depends on the task difficulty level or specific brain's function. For example, the average ApEn and SampEn values of frontal and occipital lobes increased in presence of music. This result shows that the music distracted the subjects and resulted in more complex and irregular signal in these regions.

According to the statistical test, it only indicated the significant result obtained for different Stroop tasks. In other words, the analysis results obtained for different stress groups and brain lobes were insignificant in this study. Therefore, based on this significant results, it was found that the background music can release subjects' stress and improved their task performance as beta power decreased with faster response speed and higher rate of accuracy. However, it created distraction to our brain due to higher complexity and irregularity signal which may cause by any unpredicted reasons as human brain was a complicated organ. This needs further research.

5.2 Recommendations

In this study, the EEG signal was recorded by using Emotiv EPOC+ headset which is portable and user friendly. However, it can be occasionally difficult to use during data acquisition due to the thickness of subjects' hair or head size. For example, different people with different hair style require different adjustment of the headset and it would take longer time for adjustment. Since the headset consists of numerous electrodes to receive the signals from the brain, it is easy to detect the subjects who have the shorter and thin hair style but may get poor signal towards the one who have a longer and thicker hair style.

Other than that, the subjects that mainly focused in this project were from the age ranging of 20 to 25 years and all results were analyzed among all subjects without separated into different gender. Therefore, we can choose and consider subject from different walks of life and analyze them into different gender in future study. Besides, only one type of music that was used in the research. Thus, different music genre can be used in future work to obtain deeper analysis.

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APPENDICES

APPENDIX A: Consent Form

CONSENT FORM

RESEARCH TITLE:

ANALYSING AND MONITORING OF STRESS LEVEL BY USING EEG

RESEARCHER’S NAME : NG JIAN TONG

REGISTRATION NUMBER : 13AGB03420

Purpose of This Study

The purpose of this study is to analyze and monitor the stress level by using EEG. In this study, the collected EEG data will be used for research purpose only.

Qualification of Participations

Basic requirements for an individual to participate in this EEG experiment:

1) Any gender (male or female).
2) No mental disorder or health problem.
3) No physical disorder that can affect the general well-being etc.

An individual cannot participate in this EEG experiment if one of the following applies:

1) Not willing to sign the consent form.
2) Head surgery has been performed.
3) Under daily medication.
4) Skin allergies.
5) Any psychological disorders.

Note**: If any of the above condition present in participant, please contact the researcher as soon as possible.

<u>Preparation at home</u>

Please ensure that the following steps must be fulfilled before you come to attend the experiment.

- Wash and dry your hair before hand
- Do not use gel and hairspray
- Do not use make-up or any face cream
-

<u>Experiment Procedure</u>

Firstly, a consent form will be given for participant endorsement and a questionnaires need to be answered before the experiment start. Once all the paper works have been completely done, the participant will be required to wear an Emotiv EPOC+ headset for experiment setup preparation. After all the setup has been done, the experiment will start to take place, in which the experiment processes are described as bellow.

Experiments:

1. 2 ½ minutes of EEG recording with eyes open and 1 minute rest time.
2. 2 ½ minutes of EEG recording with eyes closed and 1 minute rest time.
3. 2 ½ minutes of EEG recording with listen to music and 2 minute rest time.
4. EEG recording for approximately 120 seconds of Stroop color-word test: Congruent and follow by 1 minute rest time.
5. EEG recording for approximately 120 seconds of Stroop color-word test: Incongruent and follow by 1 minute rest time.
6. EEG recording for approximately 120 seconds of Stroop color-word test: Congruent + Incongruent and follow by 2 minutes rest time.
7. Repeat step 4 to 6 while listen to music.
8. End of experiment.

Note**: Please kindly note that any movements, adjustments, blinking of eyes and lose of concentrations should be avoided during the EEG recording process. However, all of these can be done during the rest time.

Risk

There do not have any risks involved in this experiment.

Reporting Health Experiences

Please kindly inform the researcher if there have any issues or other unusual health experiences during this study.

Participation in the Study

It is extremely voluntary for an individual to participate in this study. An individual have the rights to refuse the participations or stop it at anytime. The participations may also be stopped by the researcher if an individual fails to follows the proper instructions given.

Confidential

The information of an individual will be kept confidential and will not be made public unless disclosure is requires by law.

Data obtained or collected in this study do not identify any particular individual that will be used for knowledge purposes only.

By signing on the consent form, an individual's acknowledgment, recording authorization, review and storage of information are described as above.

Signatures

In order to participate in this study, an individual must sign and date the signature pages. (will be signed during the experiment day)

APPENDIX B: Signature Page of Consent Form

PARTICIPATION INFORMATION AND CONSENT FORM

(SIGNATURE PAGE)

RESEARCH TITLE:

ANALYSING AND MONITORING OF STRESS LEVEL BY USING EEG

RESEARCHER'S NAME : NG JIAN TONG

In order to participate in this study, you or your personal representative must sign on this page.

By signing this page, I am confirming the following:

1) I have read and understand all of the information in this Subject Information and Consent Form including all the experiment procedure, qualifications and also the risks in this study.
2) All the questions have been answered by the researcher for clearly understanding.
3) I agree to be part of this research study and follow the study procedures as researcher said.
4) I agree that the collected data may be used for future research and store securely.
5) I might be stop to participate in this study at any time.
6) I have retained a copy of this Subject Information and Consent Form for myself.

______________________	______________________
Participant Name	I.C No. (New)
______________________	______________________
Signature of Participant	Date (dd/mm/yy)

APPENDIX C: Perceived Stress Scale (PSS-14) Questionnaire

Name:____Date:____________

Age: _________ Gender: _________ Status: Degree / Master / PhD / Others

<u>Perceived Stress Scale – 14 (PSS -14) Questionnaire</u>

The questions in this scale ask you about your feelings and thoughts during the last month. In each case, you will be asked *how often* you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is answer each question fairly quickly. That is, don't try to count up the number of times you felt a particular way, but rather indicate the alternative that seems like a reasonable estimate.

Item	never	almost never	sometimes	fairly often	very often
1. In the last month, how often have you been upset because of something that happened unexpectedly?	○	○	○	○	○
2. In the last month, how often have you felt that you were unable to control the important things in your life?	○	○	○	○	○
3. In the last month, how often have you felt nervous and "stressed"?	○	○	○	○	○
4. In the last month, how often have you dealt successfully with irritating life hassles?	○	○	○	○	○
5. In the last month, how often have you felt that you were effectively coping with important changes that were occurring in your life?	○	○	○	○	○

6. In the last month, how often have you felt confident about your ability to handle your personal problems?	○	○	○	○	○
7. In the last month, how often have you felt that things were going your way?	○	○	○	○	○
8. In the last month, how often have you found that you could not cope with all the things that you had to do?	○	○	○	○	○
9. In the last month, how often have you been able to control irritations in your life?	○	○	○	○	○
10. In the last month, how often have you felt that you were on top of things?	○	○	○	○	○
11. In the last month, how often have you been angered because of things that happened that were outside of your control?	○	○	○	○	○
12. In the last month, how often have you found yourself thinking about things that you have to accomplish?	○	○	○	○	○
13. In the last month, how often have you been able to control the way you spend your time?	○	○	○	○	○
14. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	○	○	○	○	○

APPENDIX D: Music-Stress Questionnaire

Name: ____Date: _______________

Age: ________ Gender: ________ Status: Degree / Master / PhD / Others

<u>Music-Stress Questionnaire</u>

1. What genres of music do you enjoy listen to? (Can select more than one)

- ☐ Country
- ☐ Jazz and Blues
- ☐ Easy listening / music without lyrics
- ☐ Electronic (all subgenres) / metal
- ☐ Hip-Hop/Rap
- ☐ Rock
- ☐ Pop (mainstream genres eg. pop-rock, "radio" music)
- ☐ EDM (dupstep, house, techno)
- ☐ Ska (including Ska punk and Reggae)
- ☐ Rhythm & Blues (R&B, especially contemporary R&B

2. How enthusiastic are you about listening to music?

- ○ Not Enthusiastic
- ○ Somewhat Enthusiastic
- ○ Enthusiastic
- ○ Very Enthusiastic
- ○ Absolutely Enthusiastic

3. Does music help you deal with stress?

- ○ Yes, significantly
- ○ Yes, partially
- ○ Not really
- ○ Not at all

4. How many hours a day on average would you say you consciously listened to music?

- 0 - 1 hour
- 1 - 3 hours
- 3 - 5 hours
- 5 - 7 hours
- 7 - 9 hours
- 9 - 12 hours
- More than 12 hours

5. How often do you listen to music while you do homework?

- Never
- Barely
- Sometimes
- Frequently
- Always

6. How often do you listen to music while you study for an exam?

- Never
- Barely
- Sometimes
- Frequently
- Always

7. How often do you listen to music while you exercise?

- Never
- Barely
- Sometimes
- Frequently
- Always

8. How often do you listen to music when you're in physical pain? For example, headache, stomach ache, muscle ache, etc.

- Never
- Barely
- Sometimes
- Frequently
- Always

9. How often do you listen to music when you're sad?

- Never
- Barely
- Sometimes
- Frequently
- Always

10. How often do you listen to music when you're angry?

- Never
- Sometimes
- Always
- Barely
- Frequently

11. How often do you get stressed?

- Very often during a day
- A few times a week
- A few times a year/Not enough to remember
- A few times a day
- A few times a month

12. What are sources of stress for you? (Can select more than one)

- Family problems
- Work
- Mental illness
- School
- Elder/Child care issues
- Addictions
- Financial issues
- Health concerns
- Legal issues
- Time management
- Grief and loss
- Change management
- Communication difficulties
- Anger management
- Relationship issues

APPENDIX E: Emotiv EPOC+ Headset Set Up Process

According to Emotiv Epoc User Manual, (2014), the detail of set up process will be illustrated as below:

Setp 1: Hydrating the sensors and sensors assembly

There are total of 16 white felt inserts inside the Saline Hydration Sensor Pack. All of these inserts will be attached in the arms of headset which must be wetted by using saline solution. However, it should only be wet to the touch instead of soaking wet. Therefore, each of the felt inserts inside the pack should be checked to be wetted properly before used. If there are any felt inserts with insufficient wetted, one or two drops of saline solution must be added. Besides, the large white hydrator pad can be saturated by shaking the closed hydrator pack after few drops of saline are added to it. This will help to maintain the moisture for each of the inserts when they are not in use. Based on the figure below, it shown the graphic view of how to add the saline solution in order to keep the felt inserts wet.

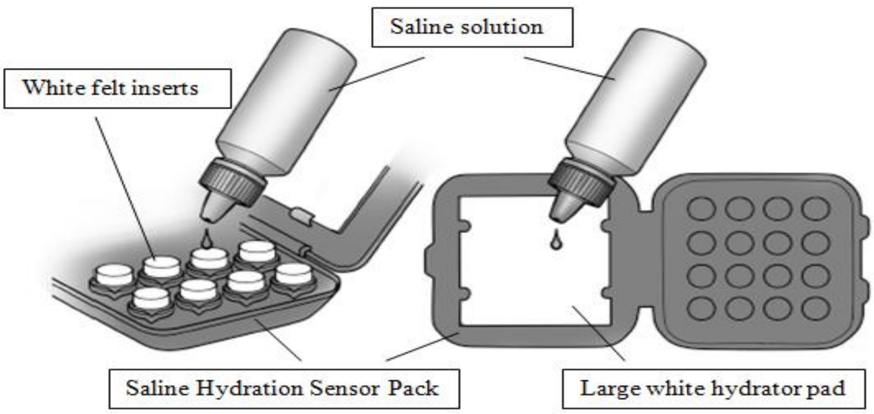


Figure E1: Saline Hydration Sensor Pack and Saline solution (Emotiv Epoc User Manual, 2014)

Once the wetting process is completely done, all the sensor units and the wetted felt inserts are removed from the pack and mounted it into the headset arm. After that, the definite “click” can be felt by the way of turning the sensor units in clockwise direction. It will indicate that the sensor had fit and installed correctly in the headset arm. If there have any difficulties, a little more force is applied until the user feel it, yet be aware that too much excessive force might cause the damage to the sensor. When sensor units are not in use, it can be removed by just turning the sensor units in anticlockwise direction as shown in Figure 2.

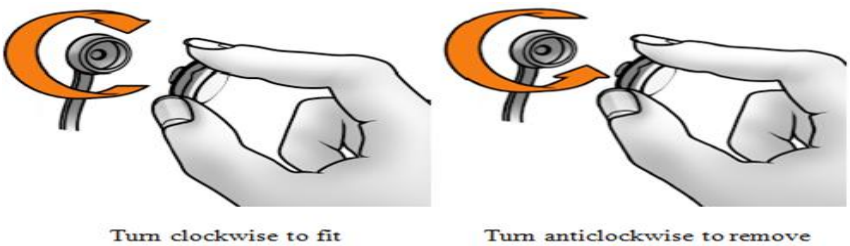


Figure E2: Way to Fit and Remove the Sensor Unit from Headset Arm (Emotiv Epoc User Manual, 2014)

<u>*Step 2: Headset pairing*</u>

In order to pair the headset, the USB Transceiver Dongle is required to be inserted into computer’s USB port. When the transceiver has paired with the nearby headset, it can be noticed that a single LED would flash slowly after one or two seconds. The transceiver should automatically recognized by the computer to indicate that the hardware is ready to use. After that, the headset is turned on by using the switch at the headband rear and holds it close to the USB transceiver. If the headset is paired, it can notice that a new steady LED (blinking rapidly) will show on the receiver.

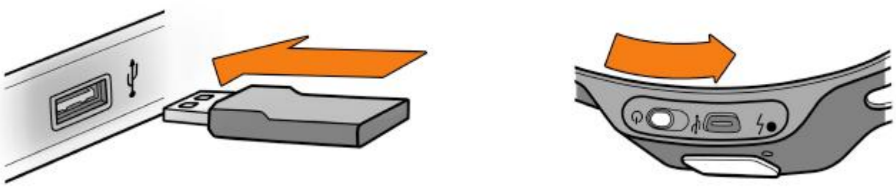


Figure E3: Way of Transceiver Plug-In and Turn on the Headset (Emotiv Epoc User Manual, 2014)

APPENDIX F: Headset Placement's Procedures

Firstly, the headset is gently slide down from the top of head by using both hands just as Figure 1 - A. After that, the sensors with the black rubber inserts are placed carefully on the bone which located behind each of ear lobe in order for correct operation. Besides, make sure that the two front sensors of the headset should be placed above both eyebrows with approximate three fingers width or 2.0 to 2.5 inches for accurate placement. Once the headset is in position, the two reference sensors must press and hold for about five to ten seconds which are indicated as the arrow shown in Figure 1 – D. These reference sensors are significant as good contact of it's the key for good signal. In order to identify the condition of sensors connection, it can be noticed through the Epoc Control Panel in the computer screen (see Figure 2). Through the Control Panel, there are several colors that can be used to indicate the signal condition as classified in Table 1 below.

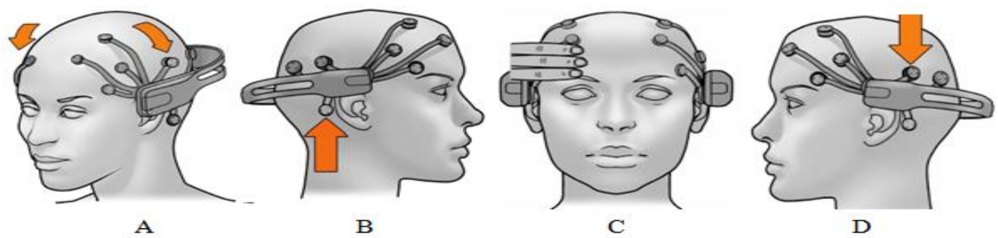


Figure F1: Headset Placement (Emotiv Epoc User Manual, 2014)

Table F1: Signal Condition Represented in Control Panel

Colors	**Condition**
Black	No signal
Red	Very poor signal
Orange	Poor signal
Yellow	Fair signal
Green plus some Yellows	(Acceptable)
Green plus Black or Orange plus Red	(Not Acceptable)
All Green	Ideal signal (most recommended)

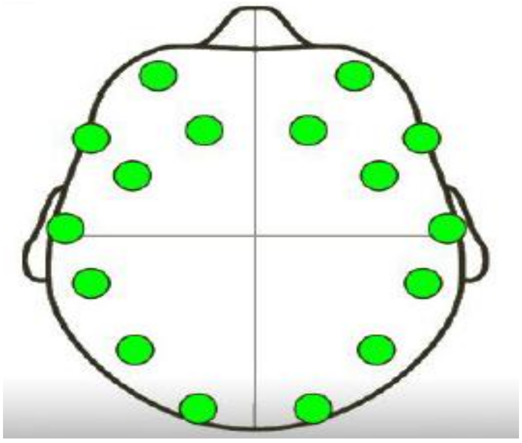


Figure F2: Signal Condition in EPOC+ Control Panel (Good Signal Condition Representation)

Based on the table, good signal will show the green color for each contact on the screen. Whenever there have any poor signal represented, it can be press and hold on the sensor for about few seconds to improve the condition. If still poor signal, the sensor unit must be checked to see whether the wetted felt insert is indeed mounted into the headset arm or not else checked for the position.

APPENDIX G: Procedures of Data Pre-processing

(Remove Artifact by Using EEGLAB)

Step 1: Open the EEGLAB in MATLAB software

Firstly, the EEGLAB can be opened by typing a command “eeglab” in the command window of the MATLAB software. It can be seen in figure below where the EEGLAB window will pop out after the command finished running. Note that the “importEEGlab().m” file must be first opened in the Editor Window before typing the command.

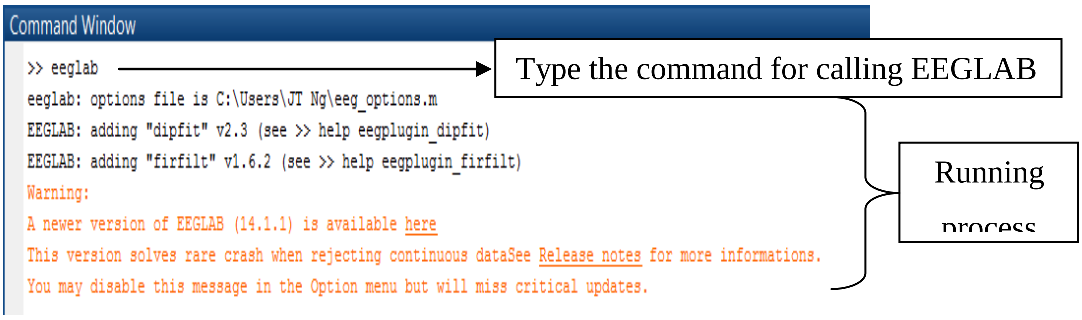


Figure G1: Command Window of MATLAB

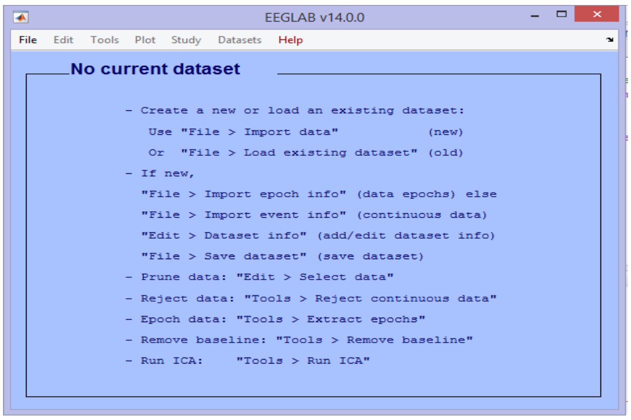


Figure G2: EEGLAB Window

<u>Step 2: Import the recorded EEG data</u>

After that, the recorded EEG data can be imported into the EEGLAB through the MATLAB Window. Note that the data file that is used to import into EEGLAB must be in .CSV format else it cannot be imported. Besides, the "open_file.m" file need to be opened in the Editor Window before started. The processes are shown as below:

a) In MATLAB Window – ①Browse the data folder and open it (will show all the data in the Current Folder) → ②type the command "[eegdata] = open_file()" in the command window

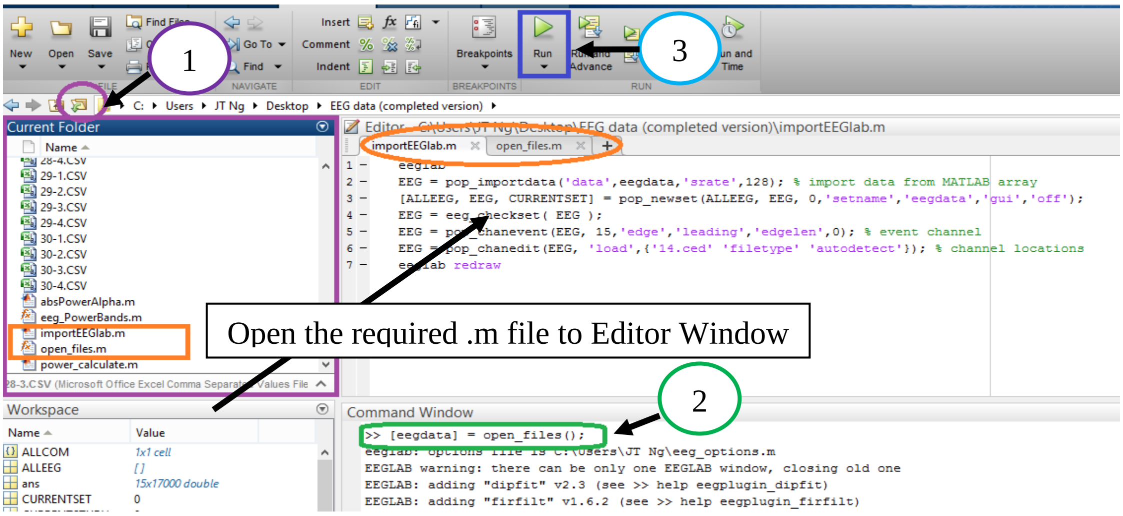


Figure F3: MATLAB Window

b) After that, the recorded data file will pop out – select the recorded data .CSV file → open → ③run the importEEGlab().m file (refer back the figure above)→ the data is imported into EEGLAB Window

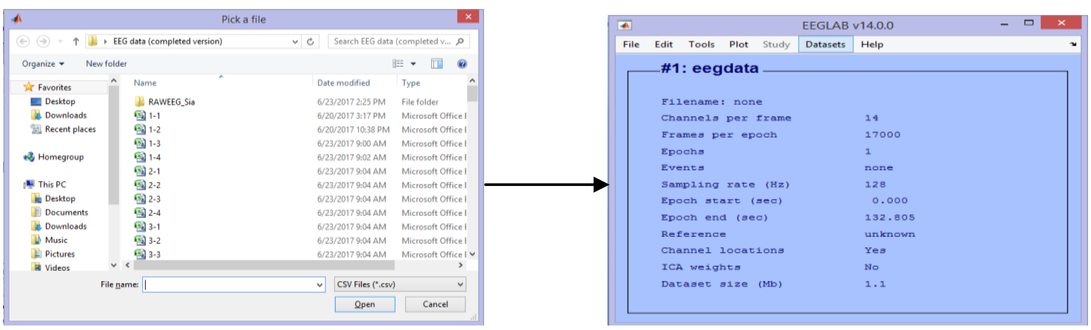


Figure F4: Import the Recorded EEG Data from Data File into EEGLAB

Step 3: Open the recorded EEG data through the EEGLAB

In order to open the recorded EEG data Window, it must first be filtered. For Emotiv EPOC+ headset, the sampling rate, *fs* that is used for recording the data is 128 Hz which is fixed. Therefore, the maximum frequency required must be less than *fs*/2 as Nyquist Theorem stated in term of signal processing so as to prevent the redundant aliasing frequency component in the data signal. In this case, the filter used and the setting value were identified as below.

a) In EEGLAB – click Tools → select Filter the data → click Basic FIR filter (new, default)

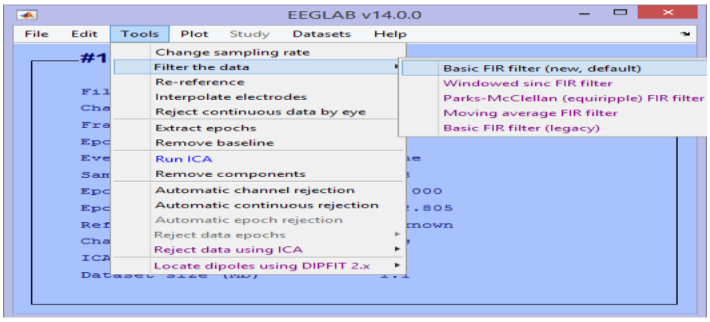


Figure F5: Selection to Open the Filter Window

b) Then the Filter Window pop out → type "1" for lower frequency pass band → type "63" for higher frequency pass band → Dataset Window pop out → click Ok

Note that the equation of Nyquist theorem, *fmax* < *fs/2* (128/2 = 64)

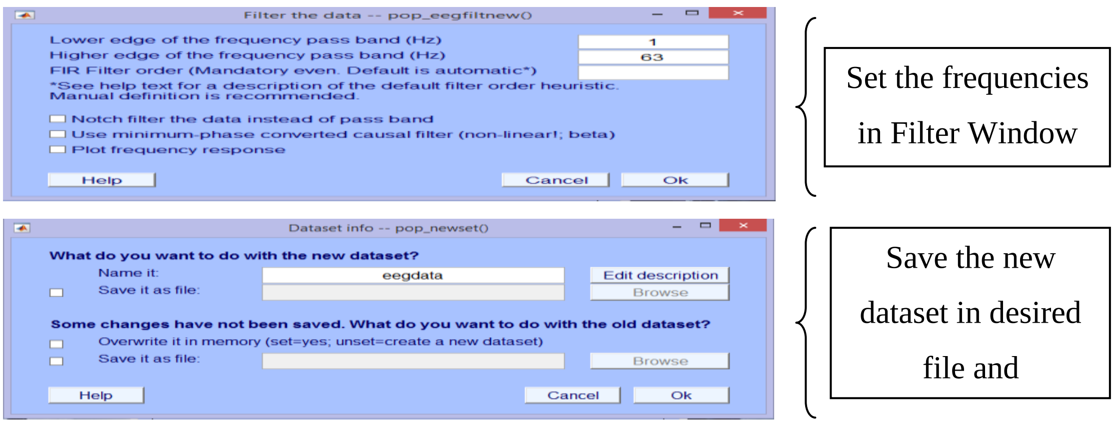


Figure F6: Filter Window and Dataset Window

c) Go back to EEGLAB Window – click Tools → select reject continuous data by eye → EEG data signal (wave view) pop out

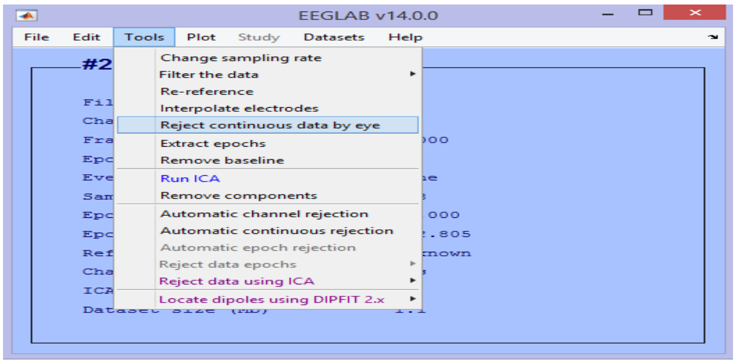


Figure F7: EEGLAB Window for Showing the EEG Data Signal

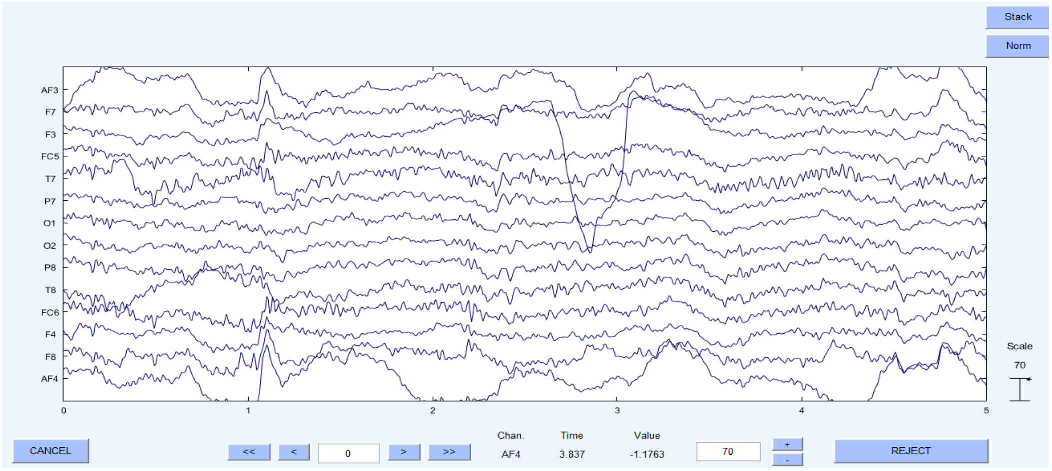
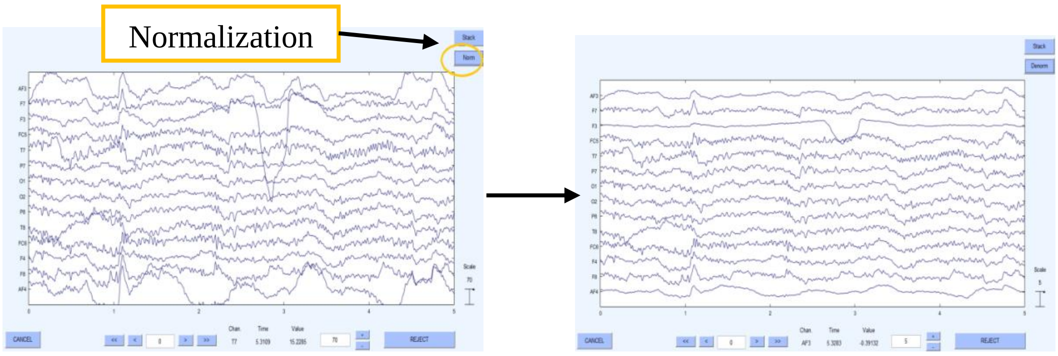


Figure F8: EEG Data Signal Window (Waveform View)

<u>Step 4: Remove artifacts</u>

Once the data waveform is shown, it must be normalized first before continue as the original signal looks "unstable" in Figure 3.9. If this step was skipped, the user may remove the correct signal instead of artifact that lead to inaccurate result occurs. After normalizing, the artifact can then be removed through the region selection in the data waveform which will be shown more detail in Figure 3.9.

a) Click the “norm” button to normalize the signal



Before normalize After normalized

Figure F9: Normalized EEG Data Signal

b) Select the artifact region → remove it through “Reject” button → save the new data

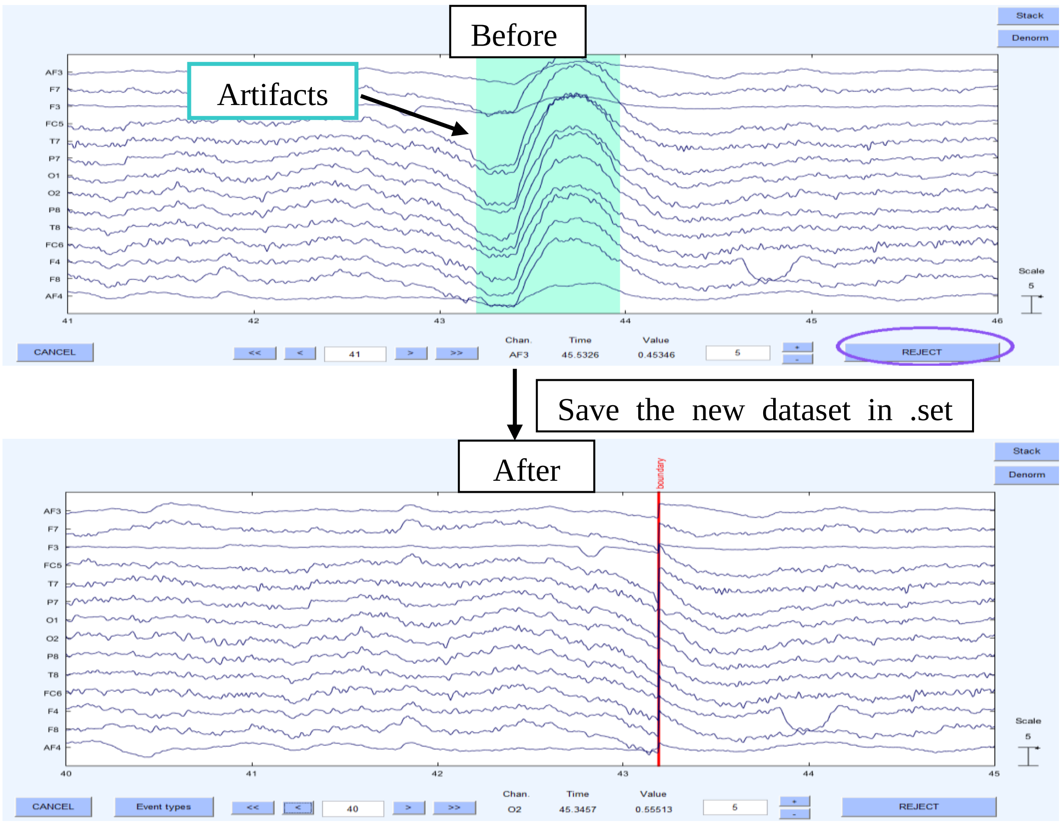


Figure F10: EEG Data Signal Before and After Remove Artifact