Brain Analysis While Playing 2D and 3D Video Games of Nintendo 3DS Using Electroencephalogram (EEG)

by

Ahmad Alif Bin Pauzi

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
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CERTIFICATION OF APPROVAL

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Approved by,

(Dr Aamir Saeed Bin Malik)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD ALIF BIN PAUZI

ABSTRACT

To be able to gain knowledge of human brain and study the perception of human towards stimulated events, emotions and sense, scientists have been using few main methods. They are Electroencephalograph (EEG), Computerized Axial Tomography (CAT) scans, Magnetic Resonance Imaging (MRI), Functional Magnetic Resonance Imaging (fMRI) and Magnetoencephalograph (MEG). These technologies, up to this date are able to help scientists, researchers and doctors to understand how brain works and doing analysis upon them. [1]. Meanwhile this project will be focusing on the usage of EEG to do the analysis on human brain. The EEG shows electrical impulses of the brain and can be recorded in form of waves. Recently, the emerging of auto stereoscopic 3D technology of Nintendo 3DS has bring new gaming experience as players can see 3D. The objective of this project is to use EEG equipment to analyse the activity of human brain when playing console game Nintendo 3DS in 2 dimensions (2D) mode and 3 dimensions (3D) mode. The purpose of this project is also to study and compare on human brain perception of 2D and 3D gaming. Our brain perceives 2D and 3D moving images of video games differently, and we would want to study how different they are. In the end, this project will be able to explain and conclude how human brain responds to 2D and 3D gaming of Nintendo 3DS console game and what difference they make in human visual system of brain.

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

1.1.1 Electroencephalography (EEG)

Electroencephalography (EEG) is a recording activity of electrical signals generated from the brain, made by putting up electrodes to the subject's head scalp. Hans Berger (1873-1941) discovered the existence of EEG tracing, as he began his research upon human EEG in 1920 [2]. By using EEG equipment, we may diagnose brain disorders and human behaviour from the generated brainwaves. EEG allows researchers to trace and record electrical impulses in form of waveform signals across the surface of the scalp and changes over split seconds can be observed. A state of a person can be seen from the EEG such as focused, awake, dizzy, drowsy, or defocus because the patterns of EEG signal differ from one to another state. One important use of EEG is to show the time taken by brain to process various type of stimuli be it graphical, audio or moving images [3].

EEG recording can be done by placing electrodes on human head scalp. Electrodes are used to establish connection between the conducting fluid of the brain tissue and the amplifier [4]. Local current flows are formed once the neurons were activated as response to some form of stimuli. Differences of electrical potentials are caused by summed postsynaptic graded potentials from pyramidal cells that create electrical dipoles between the soma (body of neuron) and apical dendrites (neural branches) [5].

The greatest benefit of EEG is speed. It can record complex pattern of signal generated within split second of time during occurring of stimulus. With comparison to MRI and PET, lesser spatial resolution is provided by EEG. Analysers can find out the relative strengths and magnitude of electrical activity at different part of brains by EEG [6]. Biochemical, metabolic, circulatory, hormonal, ferroelectric, and

behavioural factors are reasons why state of EEG signal from a person can change[7].

Figure below shows the example of EEG electrodes placement on human head scalp and the recording of human brain activity using EEG.

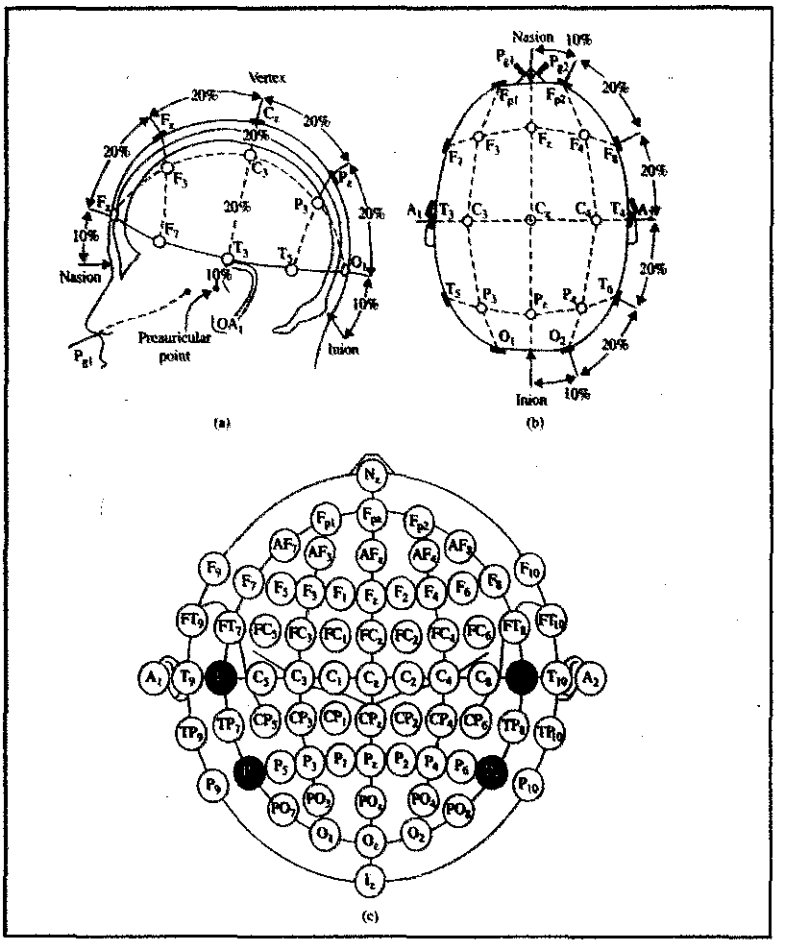


Figure 1.1 (a) 10-20 system electrode placement and (b) represent the three-dimensional measures, and (c) indicates a top view of the 128 channels electrodes.

EEG waveforms are usually have amplitude of and range from .EEG waveforms can be categorized to 4 main bands [8]:

Wave Type	Frequency Band	Brain Condition
Delta	0.5-4 Hz	Deep sleep, deep relataxion
Theta	4-8 Hz	Relaxed, drowsiness
Alpha	8-12 Hz	Relaxed
Beta	>12 Hz	Focused, excitation

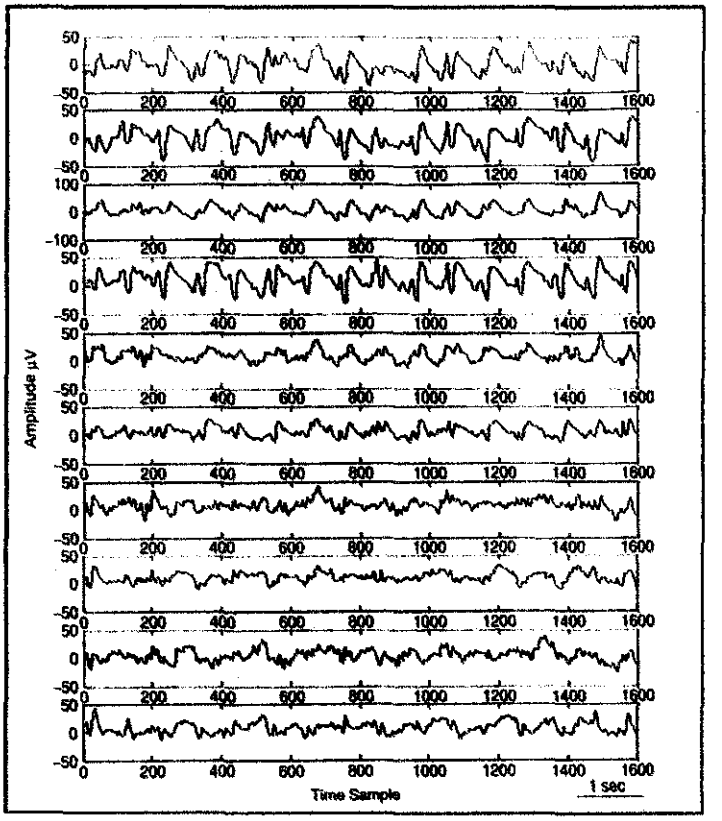


Figure 1.2: Adult's normal EEG tracing

1.1.2 Visual Evoked Potential

The evoked potentials (EPs) elicited by the physiologic activation of receptors or by the electrical stimulation of nerves combine some features of the compound nerve action potentials. EPs can be viewed as any neuronal response triggered by stimulation sensory receptors of peripheral nerves, and also any neuronal activity time-related to cognitive process or motor programming [9].

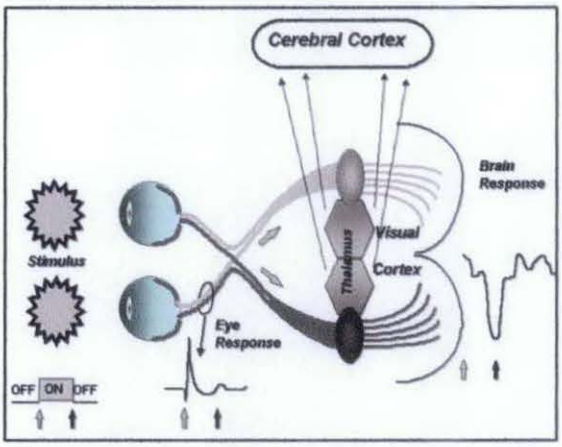


Figure 1.3: The EEG path of VEP

Visual evoked potentials (VEPs) happens when the visual field of subject respond to graphical stimuli and are observed using EEG. Waveforms can be observed at the C1 and P1 and also the visual N1 of the EEG electrodes [10].

The VEP are important in the research of abnormality and testing the functionality of visual system. Usually VEP refers to responses observed at the occipital region. In this project, 2D and 3D games of Nintendo 3DS game console will be the visual stimulus and participant will be responded by playing the games accordingly.

1.2 Problem Statement

Human brain is the most complex part of our body. It monitors and regulates the body's actions and reactions, including the visual system. Auto stereoscopic 3D of Nintendo 3DS brings new experience to users by letting them to view 3D content of game without using glass. Previous research of EEG by scientists and engineers only involved 2D games. How does human brain perceives 3D games of Nintendo 3DS compared to 2D games of Nintendo 3DS?

1.3 Objectives

The objective of this project is mainly to study and compare the human brain perception of 2D and 3D gaming of Nintendo 3DS using through designated experiments, acquiring the signals generated by brain throughout playing game using Nintendo 3DS in the experiments by using EEG equipments, and further process and analyse the signals to explain the brain activity during playing 2D and 3D game

1.4 Scope of Study

The scope of this project is doing research on human brain anatomy, psychology and nervous system, designing Event Related Potential experiments, conducting experiments using EEG equipments and further analysis of the data acquired using signal processing tools. The research is important for better understanding of how human brain perceives 2D and 3D games and what difference does them make to our brain when playing them. The outcome of this project will benefit scientist and psychiatrist in order to gain more knowledge of the differences of 2D and 3D games in human brain. Recording, processing and analyzing the EEG data and making out conclusion can be done with the project time frame of 28 weeks.

CHAPTER 2

LITERATURE REVIEW

2.1 Human Brain

Brain is the main part of our nervous system. The brain of human being has 3 interrelated layers. Stems are structure that concerned with the processes such as heart beat, breathing and controls digestive system. Enveloping this central core is the limbic system, which is involved with emotion, motivation and memory processes. These two regions limbic system and stems are wrapped around by cerebrum. The cerebrum and cerebral cortex, integrates sensory information, direct our body movements and control nonfigurative thinking and logic.

Incoming sensory information are delivered from eyes to the appropriate area of cerebral cortex, where that information is processed through long sort of fibbers that connected to thalamus. Neuroscientists have long known that the cerebellum, attached to the brain stem at the base of the skull, controls bodily movements, postures, and maintains the balance. Damage to cerebellum will interrupt the flow of otherwise smooth movements, causing human to appear uncoordinated and jerky.

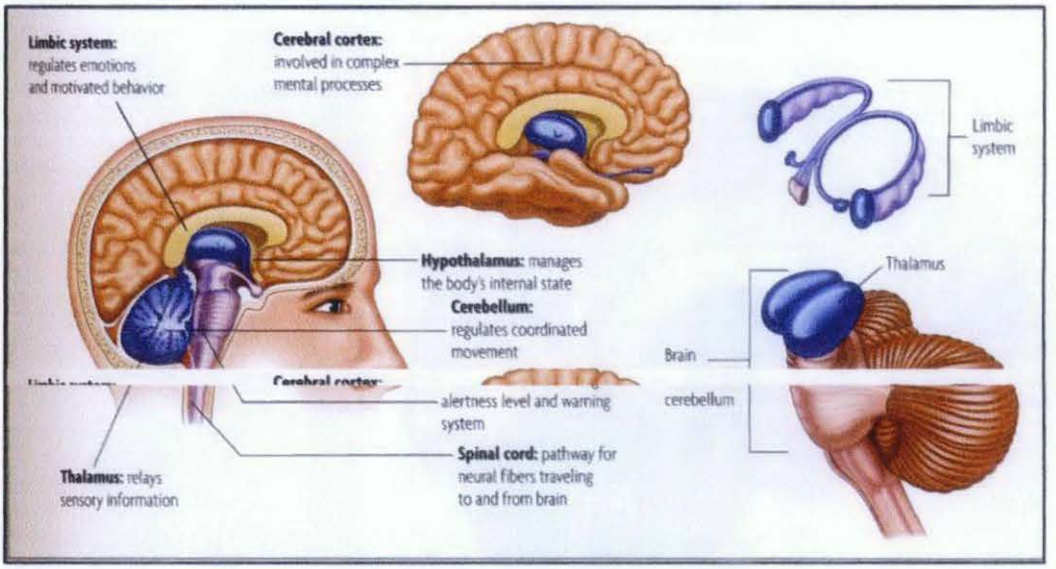


Figure 2.1.The Brain Structures

The limbic system is in charge of behaviours, memory process and stress level controls. Besides that, limbic system also regulates body temperature, blood pressure, and blood sugar level and performs various maintenance activities. The limbic system comprises three structures, they are hippocampus, amygdale and hypothalamus.

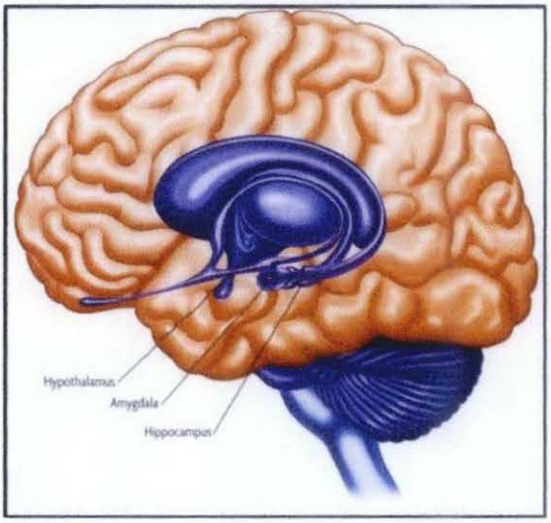


Figure 2.2: The Limbic System

The cerebrum occupies the other parts of the brain, consisting two thirds of its total mass. The function of cerebrum is to adjust the higher cognitive and behaviour function. Cerebrum's hemisphere is separated into four lobes [11]. The frontal lobe involved in motor control and cognitive activities like planning and decision making. Meanwhile, the parietal lobe is in charge for touch sense, temperature and pain. The occipital lobe is the ultimate destination for visual information from eyes, situated at the rear part of the head. Hearing and memory process are the functions regulated by temporal lobe.

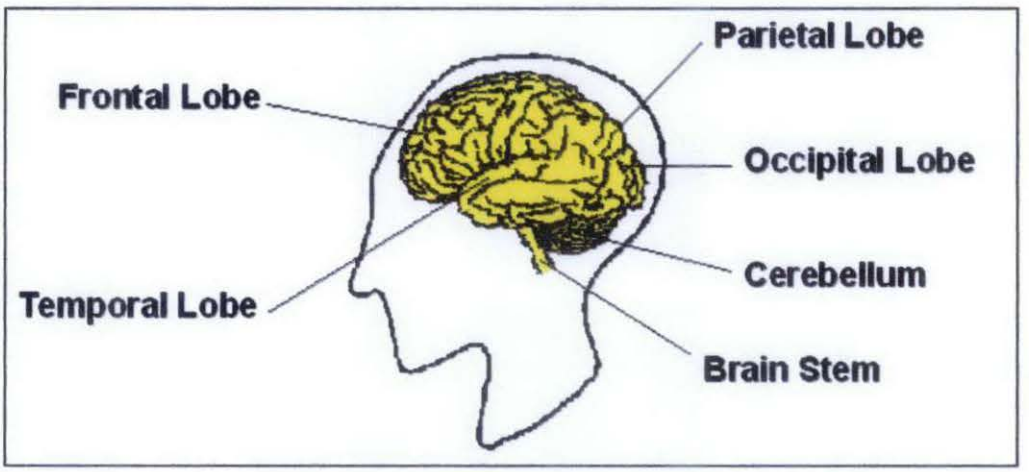


Figure 2.3: The Brain Main Lobes.

In this project, we are interested to study the visual region of human brain, to study the differences of 2D and 3D video games. Processing of visual input takes place at the rear of the brain in the occipital lobes. It is the greatest area devoted to input from eye. [12].

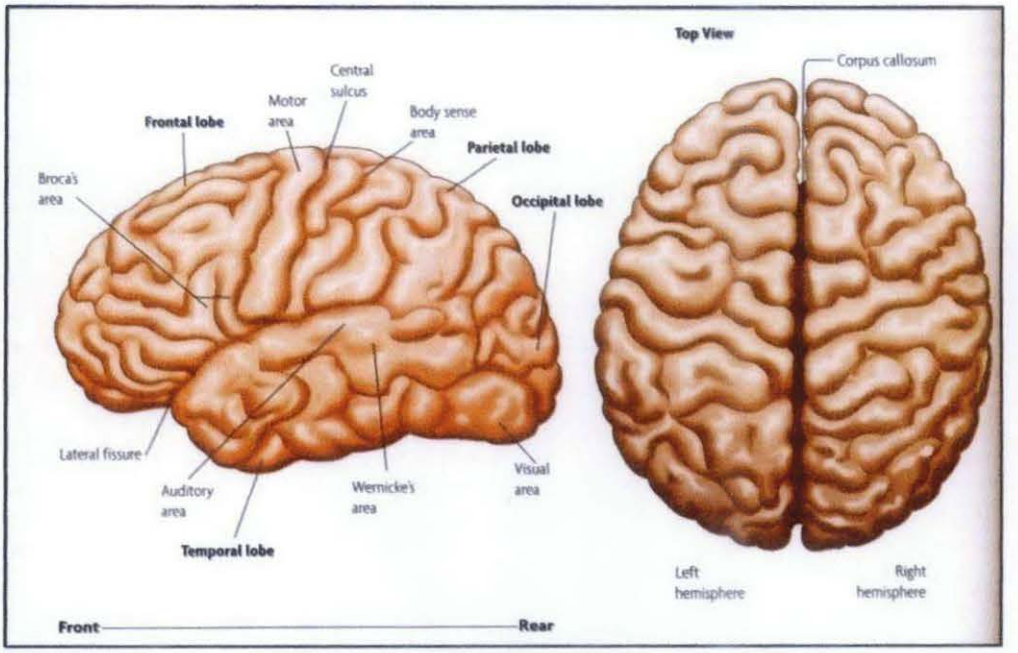


Figure 2.4.The Cerebral Cortex

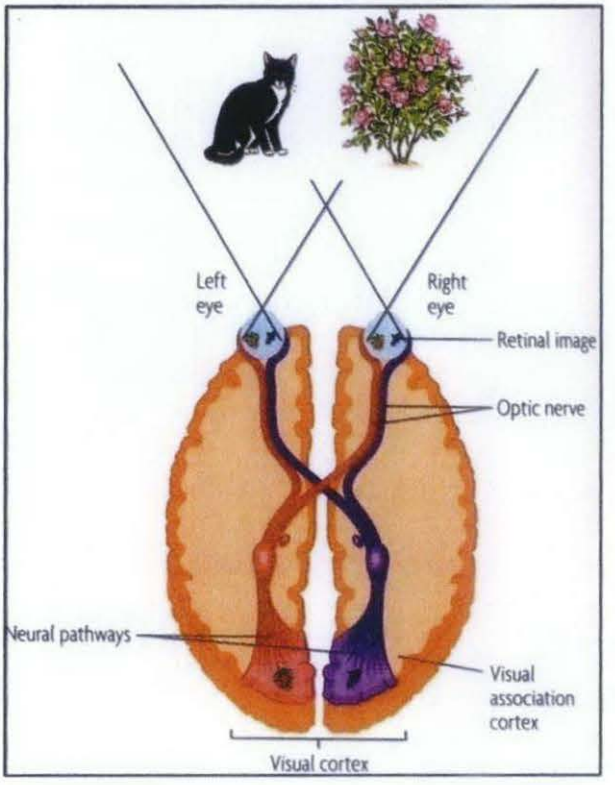


Figure 2.5.The Neural Pathways for Visual Information

2.2 Previous Study of Brain Activity during Video Game Play

In the previous study, the researchers examined the dynamic brain activity during nonstop video game play by using the high resolution EEG. Two subjects played a competitive video game, Mario Power Tennis in 2D resolution on a Nintendo Gamecube and at the same time their EEG signals were recorded same allocated time segments.

The study shows that increasing power are observed of midline theta-wave at frontal lobe as a result of video game play. Parietal alpha-wave power was observed increasing as a result of video game play, suggesting the rise of mental load. From this study, researchers can conclude from EEG analysis that long period of gaming will increase the mental load of players.

CHAPTER 3

METHODOLOGY

3.1 Methodology

This project was conducted according to this methodology to meet the objective. First thing first was to understand the objective of this project and do research on human brain, nervous system, human visual system, 2D and 3D video games of Nintendo 3DS , experiment design, EEG and signal processing. After that, series of EEG training were conducted to be able to fully understand how EEG equipments work and know how to calibrate them together to do signal recording. After that, participants were recruited for the experiments after specifying type of participant that will undergo the experiment. Then, experiments were conducted upon these participants and acquire and record the data, which is the brain signal from them using EEG equipments and Brain Master Discovery software while they are playing Nintendo 3DS in 2D and 3D. The next step was to do processing of the raw data obtained, to be able to get analyzable signals and valuable information. This step involved pre-processing and processing. After the final form of brain signal is obtained, data is tabulate and analysis was done and made conclusion from the findings about the difference on human brain perception of 2D and 3D gaming using Nintendo 3DS. The figure below simplifies the flow of methodology explained.

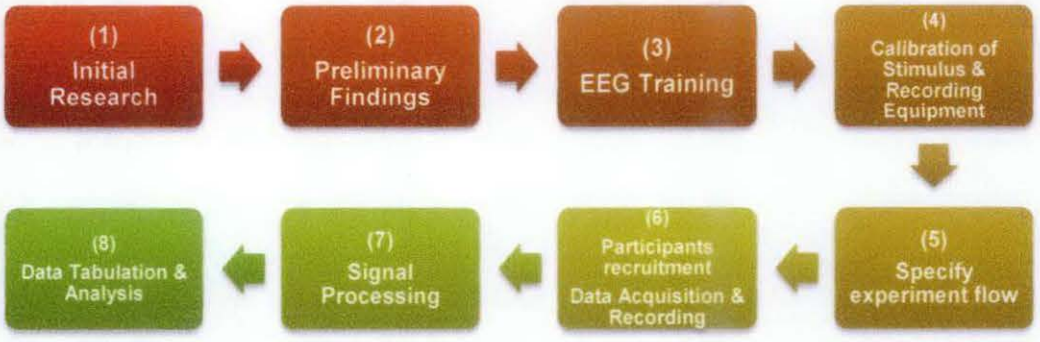


Figure 3.1: Project methodology

3.2 Project Gantt Chart & Key Milestone

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Topic Selection														
EEG Training														
Research Work														
Extended Proposal														
Participant Recruitment														
Experiment Design														
EEG Training														
Proposal Defense														
Conduct Experiment														
Interim Report														

Table 1: FYP I Gantt Chart

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Data Recording & Analysis															
Progress Report								*							
Electrex											*	*			
Draft Report													*		
Final Report														*	
VIVA															*

Table 2: FYP II Gantt Chart

* = Key Milestone

3.3 Tools

The list of the hardware and software used are according to table below:

Hardware	Software
- Nintendo 3DS & Game Tape -BrainMaster Discovery 24e Cap and Amplifier - Toshiba QOSMIO PC	- Windows 7 Operating System -BrainMaster Discovery Recording Software -NeuroGuide Deluxe 2.6.7 - Microsoft Office - MATLABMathworks v 7.10.0

Table 3: Tools required

3.4.1 Nintedo 3DS

The Nintendo 3DS is a Nintendo portable game console. It has capability to be played in auto stereoscopic 3D mode which require no glass to see the 3D effect, as well as the standard 2D mode. It is the successor to Nintendo DS game console.

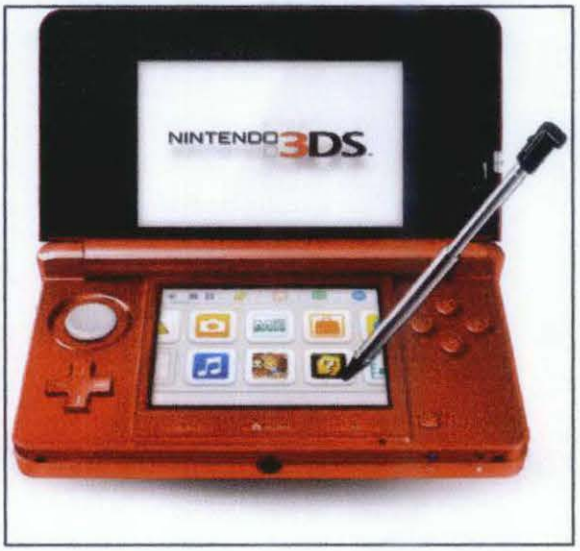


Figure 3.2: Nintendo 3DS (red colour)

This new system introduced several innovation compared to the design of the original DS, notably a slider on the side of the device which adjusts the 3D depth intensity, and also an analogue input entitled the "Circle Pad

Nintendo publically announced that the 3D mode of the 3DS is not intended to be played by children ages six and below, claiming potential impairment to their vision. It is suggested by Nintendo that young players should only play in 2D mode for safety [15].

3.4 Experiment Method

Participants in the experiment are UTP Undergraduate students, age range from 18 to 25 years old. Subjects are being filtered to make sure they are healthy and eligible to undergo the experiment. A fighting game – Super Street Fighter IV was selected. The game requires real-time active response from player where player will face character controlled by computer one on one and try to win the match by knocking out the opponent to be able to proceed to the next round. Participants able to change the mode of the game from 2D to 3D by adjusting the "3D" lever of the Nintendo 3DS beside the top screen. They are given the instructions to play the game before any recording of EEG is being done. 20 participants were involved in this experiment. The reasons of choosing this game are because it is easy to be played and produce nice 3D effect by creating depth between fighting characters and surrounding background of the game.

Figure 3.3 : Super Street Fighther IV, Nintendo 3DS

The EEG signals were recorded using 19 channels BrainMaster equipment and BrainMaster Discovery software. The EEG signals were digitized with a sampling rate of 255kHZ and notch-filter of 50kHz.

The experiment recording is started with 5 mintues eyes closed, followed by 5 minutes eyes open to get the baseline of the participant's brain. For each recording segment, the participant was asked to sit straight, minimize the eye blinks and muscle movements, as well as keeping their eyes closed and opened as much as they can, respectively to the recording segments. Then, the participant will be playing the Super Street Fighter IV of Nintendo 3DS continuously in 2D mode for 20 minutes.

After the participant finish playing in 2D, he or she will be given time to rest for a while before 5 minutes of eyes open session is being conducted. Then, the participant will be playing the same game in 3D mode for 20 minutes. The figure below shows the block diagram of the experiment segments. A questionnaire will be given to the participant at the end of playing games to be filled in (see APPENDIX) .

Figure 3.4. Block diagram of experiment protocol.

The next figure shows the experimental setup as well as sample of real-tme EEG signals obtained from a participant during playing Nintendo 3DS.

Figure 3.5. Experimental setup and obtained EEG signal

3.5 Data Acquisition And Recording

Sample size of 20 participants is being used for data recording, consist of their EEG signals. The hardware and software use for recording EEG signals are BrainMaster 24e cap, amplifier and Toshiba Qosmio PC with BrainMaster recording software installed. Before start of each experiment/recording session, the participant will need to fill in their particular information such as name, age, gender and will be asked to sign a consent form and state that he or she is participating in experiment voluntarily.

After that, experimenter will setup the participant with BrainMaster 24e cap which consists of 19-channel electrodes and linked-ear montage. A conductivity gel is injected inside each of electrode to make sure good connection between the electrodes and participant's scalp. The impedance of each electrodes are being

measured to make sure they get below 5 k Ohm value. The cap is connected to amplifier and the amplifier is connected to recording PC to record EEG Signal. Experimenter will check all the settings of software before proceeding to make sure all the parameters are correct.

Figure 3.6: Brainmaster Discovery cap and amplifier

After explaining the flow of experiment to the participant, experimenter will start the experiment and record the EEG signals using BrainMaster Software throughout the experiment time frame as mentioned earlier in experiment method part. The raw EEG signals recorded are being saved in EDF format.

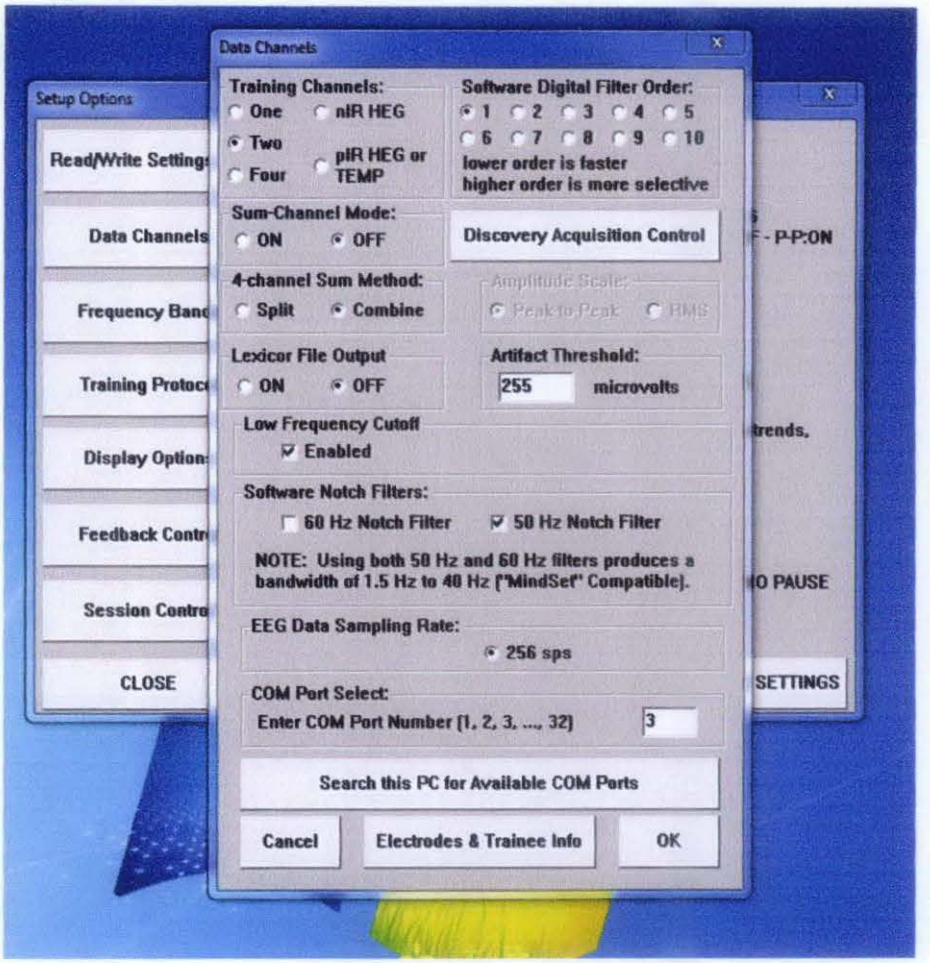


Figure 3.7: Settings for Brainmaster recording software

Figure 3.8: Recording window

3.6 Pre-Processing

After raw EEG signal is obtained, the next step is to do pre-processing. Before we process and compare the difference between 2D and 3D games of Nintendo 3DS, it is essential to do pre-processing which include several steps: artefacts rejection (consists of drowsiness, eye-blink and eye movement rejection) plus automatic selection. This pre-processing is done by NeuroGuide Deluxe 2.6.7 software.

Signal distortions are called artefacts. It is a sequence with higher amplitude and different shape in comparison to normal EEG signal sequences. The artefact in the recorded EEG can be classified as patient-related or technical. Patient-related artefacts are those unwanted physiological signals that may significantly disturb the EEG signal pattern. Technical artefacts can be reduced by decreasing the electrode impedance[16]. Table below shows the classification of EEG artefact.

Patient-Related Artefact	Technical Artefact
-Eye blinks and eye movement	-50/60 Hz AC power line noise
- Major body parts movement	- Impendence fluctuation
-Sweating	- Cable movements
-Irregular heartbeat	- Too much electrode gel / dried gel

Table 4: EEG artefact classification

The first step of pre-processing is to import raw EEG data recorded previously, session by session into NeuroGuide. Subject information is being filled and correct montage (link-ear) is selected from left panel of the software. The next step is to select 10 seconds artefact-free EEG signal to be used as template / reference for the software. After the 10 seconds template has been carefully chosen and selected, artefact rejection can be done by clicking Edit->Artefact Rejection->Drowsiness Rejection. Eye blinks and eye movements artefact can be eliminated by

Edit->Artefact Rejection->Eye Movement Rejection. Black line below the signals indicates that the signal has been removed and will not be taken into account when doing processing later on.

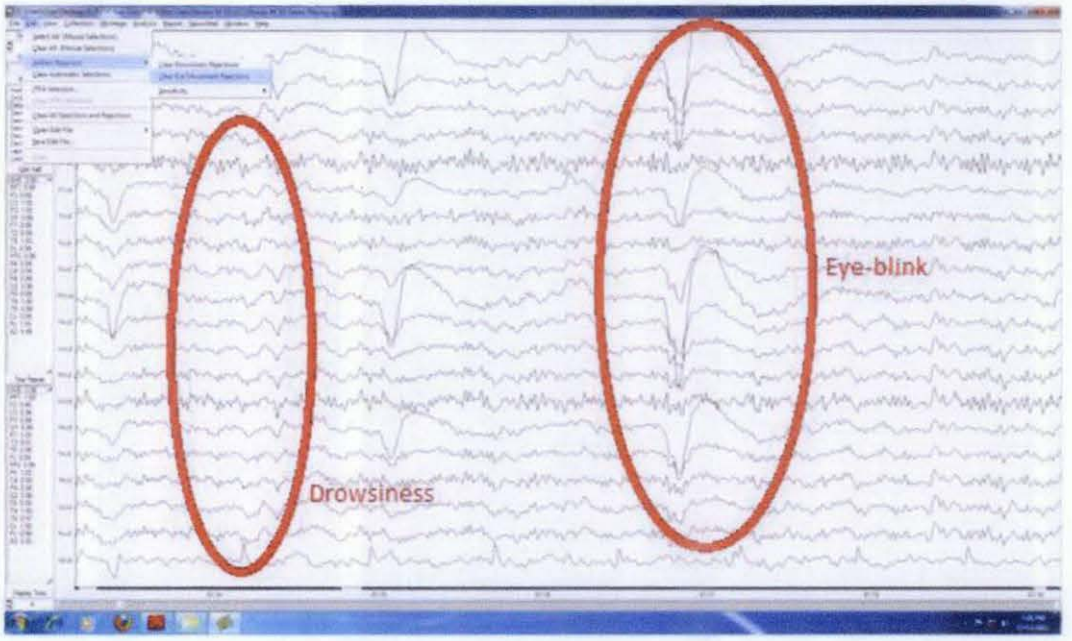


Figure 3.9: NeuroGuide artefact rejection

After artefact rejection has been done, the next step is to select the remaining good portion of EEG signal to be analysed. The NeuroGuide can automatically select the good EEG signal by Edit->Automatic Selection. It detects the similar pattern from the 10 seconds template which chosen before to determine good parts of EEG signal. Red line below the signals indicates that the portion of signals are being selected for processing.

Pre-processing is done to all EEG raw data recorded. A participant will have a total of 11 sets of raw data comprise of eyes closed 2D, eyes open 2D, four 5-minutes segments of 2D game-playing(5,10,15,20 minutes), eyes open 3D, four 5-minutes segments of 3D game-playing(5,10,15,20 minutes)

Figure 3.10: Neuroguide selected EEG signal

After the pre-processing completed, the edited EEG data is saved in NeuroGuide(*ng) format.

3.7 Processing

Processing of the cleaned signal is started by generating a report from NeuroGuide software containing desired information of the EEG signal such as Z-Scored absolute power, coherence and phase lag values. EEG signal recorded by participant will be compared with a normative database inside NeuroGuide. This can be done by Report->Generate Report. Before that, information that wanted to be generated can be selected through Report->Report Selection.

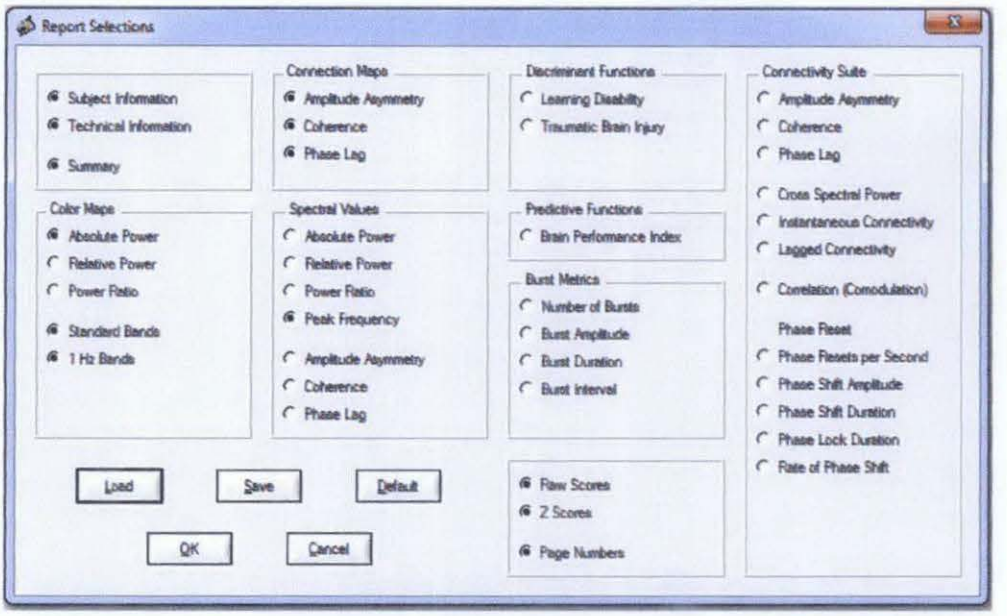


Figure 3.11: NeuroGuide Report Selection.

The report generated will contain the value for each frequency bands and 19 electrodes. This values, are saved in Tab Delimited Text (*TDT) and can be opened using Notepad in Windows Operating System.

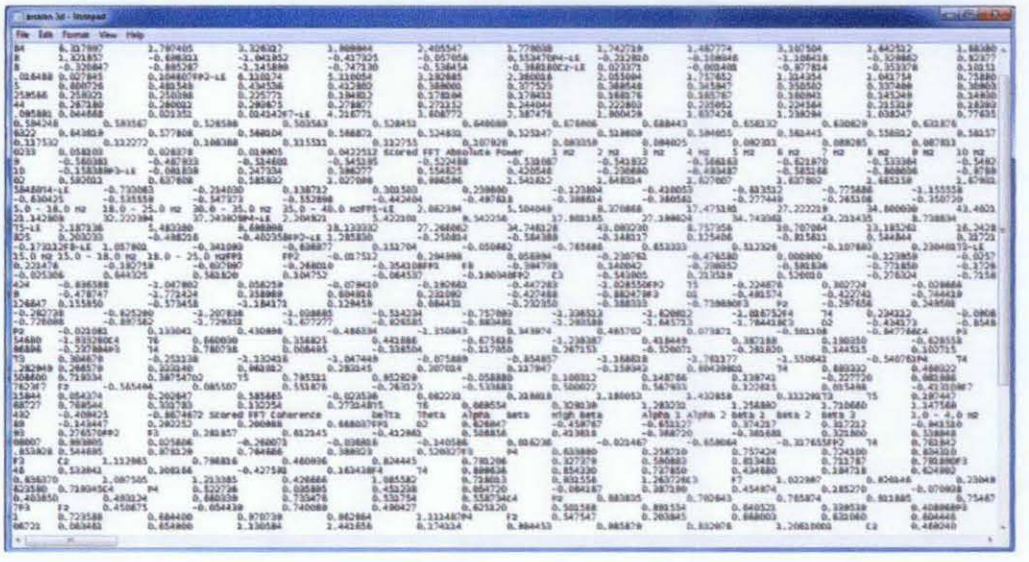


Figure 3.12: Z-Score values in TDT format opened using Notepad

To be able to see the values correctly, the TDT is furthermore exported to Microsoft Excel sheets.

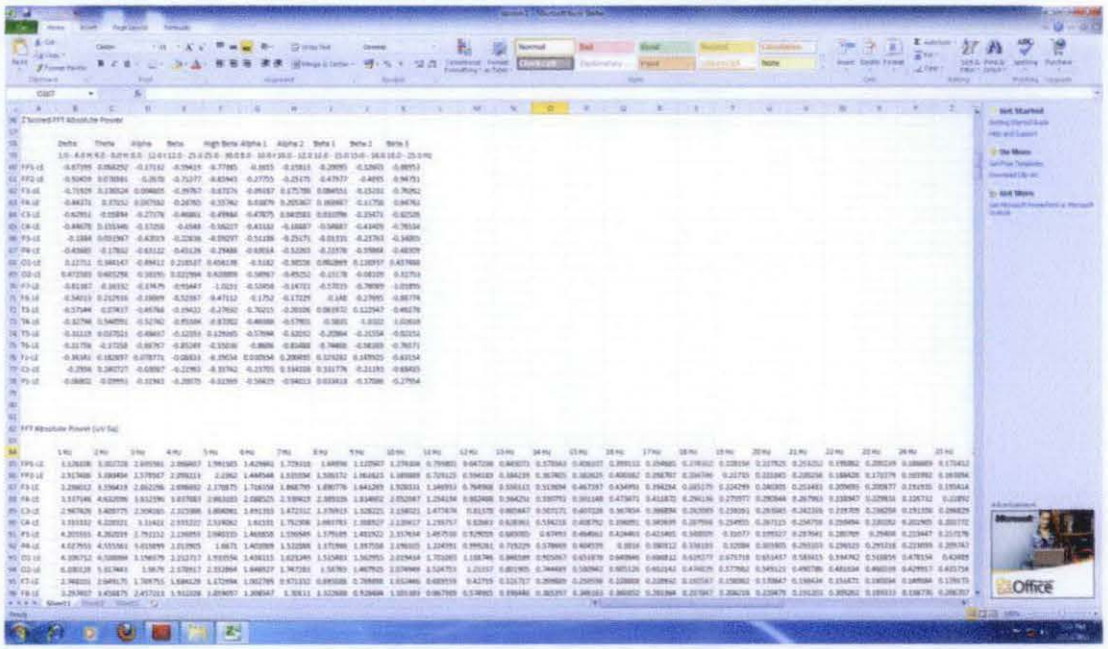


Figure 3.13: Z-Score values in Excel sheets.

In order to make comparison between the EEG signal of 2D and 3D, the data from each segment of 2D and 3D game-playing of every participant are being imported to MATLAB for further processing. In MATLAB, codes are written to get Z-Scored values of absolute power, coherence and phase lag from 2D and 3D and mathematical as well as logic operations are done to find the difference between 2D and 3D values.

The difference of absolute power, coherence and phase lag maps and bar charts for each frequency bands Delta, Theta, Alpha 1, Alpha 2, Beta 1, Beta 2, Beta 3 and High-Beta for every electrode are being plotted and the matrix values are saved for results analysis.

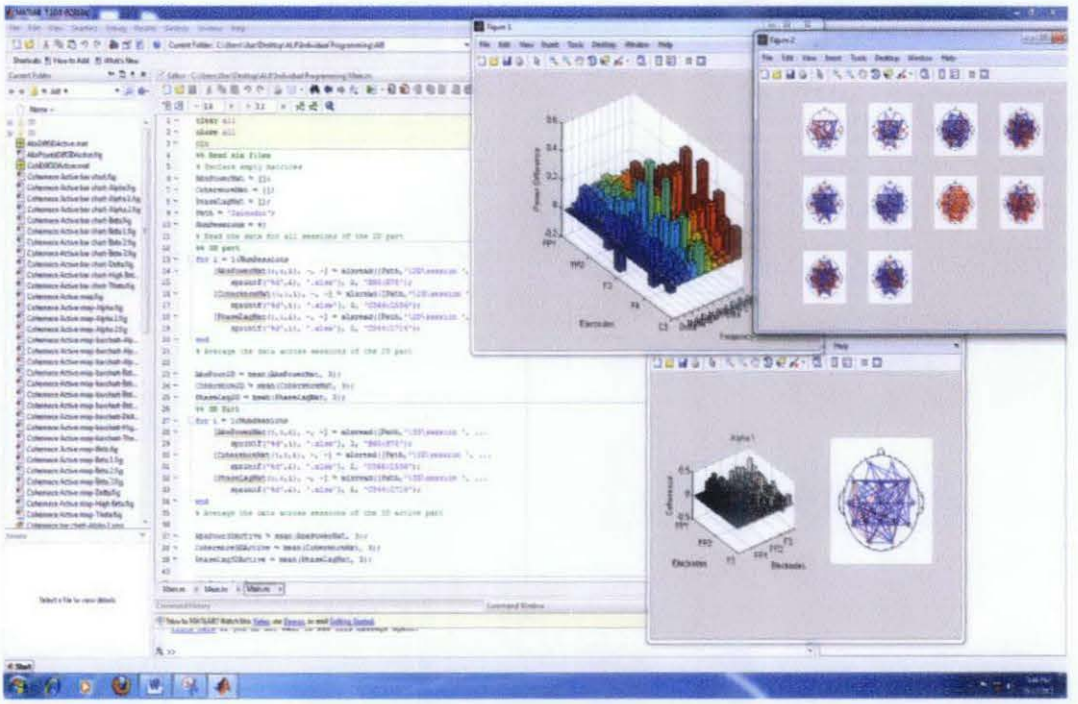


Figure 3.14: Data processing in MATLAB 7.10.0.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Z-Score

Z-Score is a metric based on any measurement and the associated population statistics. It tells "how many standard deviations away from the mean" [17].

$$Z\ score = \frac{(Measurement - Mean)}{Standard\ Deviation}$$

Z-Score range can be from +/- 1 Sigma to +/- 4 Sigma. When analysing the resulting waveform obtained from experiment, we are interested in 3 criteria which are absolute power of spectrum bands (Delta, Theta, Alpha, and Beta), coherence and phase lag.

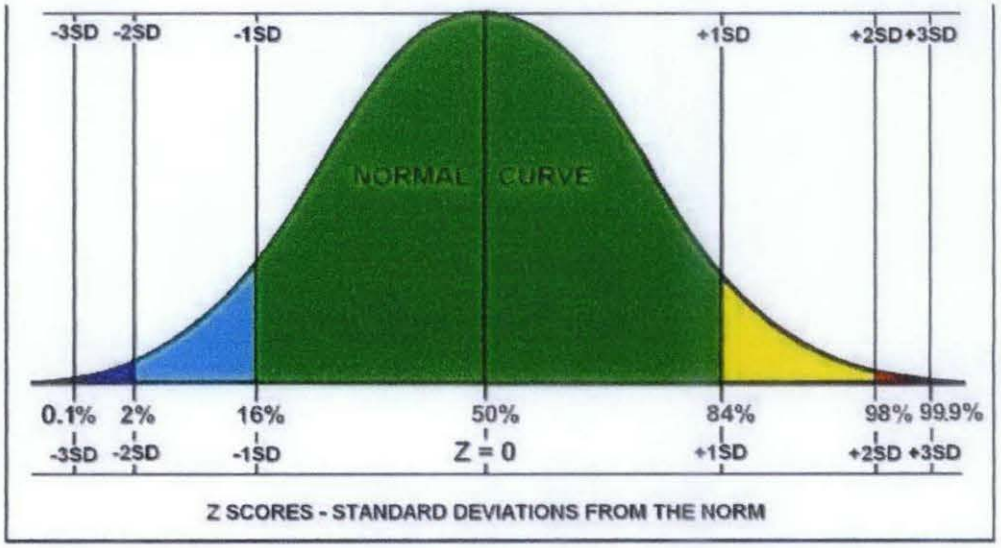


Figure 4.1 : Z-Scores Normal Distribution Graph

4.2 Absolute Power

Absolute power is defined as the summation of all powers within the specific frequency band, expressed in μV^2 [18]. The figures below shows the result for absolute power difference between 2D and 3D at Occipital Lobe, the area where human perceives visual information.

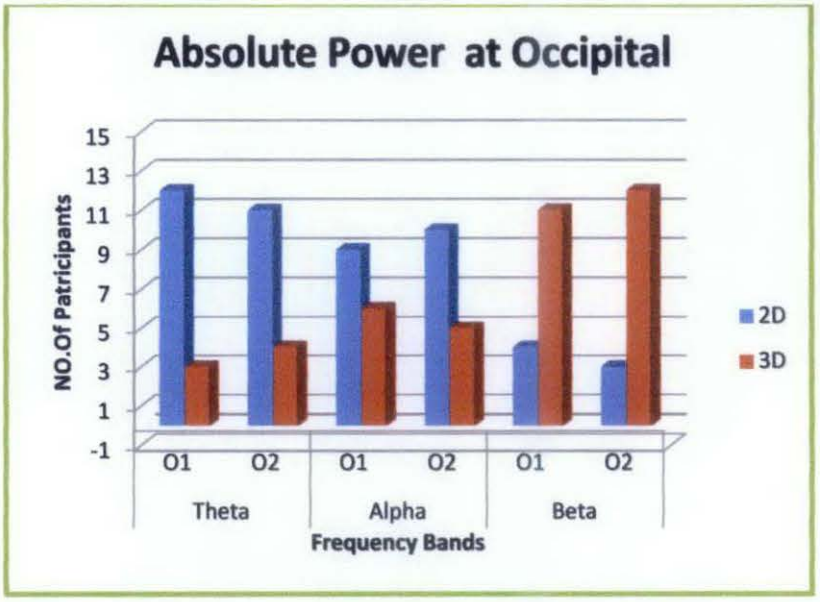


Figure 4.2 : Absolute Power at Occipital Lobe

From this graph, Theta absolute power is higher in 2D suggests that most of the participants are learning because most of them never played Nintendo 3DS before. Higher Theta and Alpha in occipital lobe in 2D also suggest that the participants are more relaxed while playing games of Nintendo 3DS in 2D mode compared to 3D.

Meanwhile absolute power of Beta is higher in most of participants in while playing 3D compared to 2D suggests that more concentration are needed when play games in 3D compared to 2D. This also indicates that 3D mode of Nintendo 3DS give more arousal to human visual system, thus increase attention level.

4.3 Coherence

Coherence is the stability of the phase relationship over time between two sites (electrodes), it's a measurement of information sharing. Figure below shows the

result of coherency between electrodes of different brain regions which are related to video gaming.

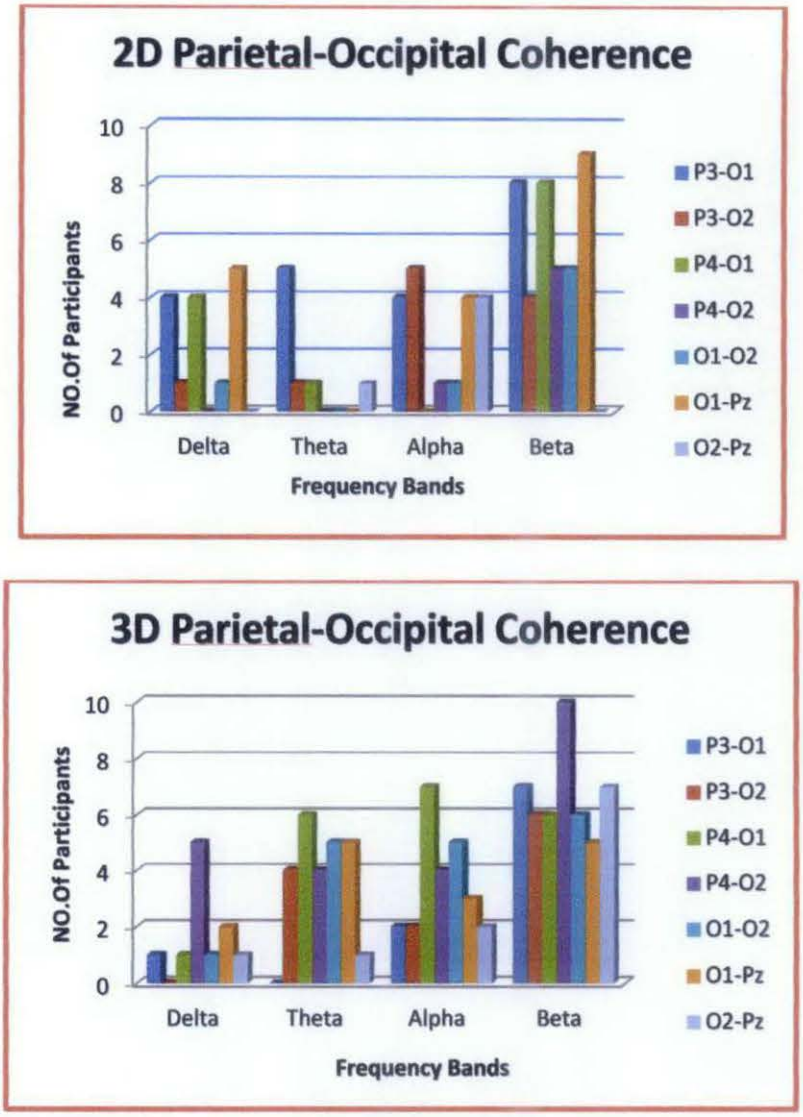
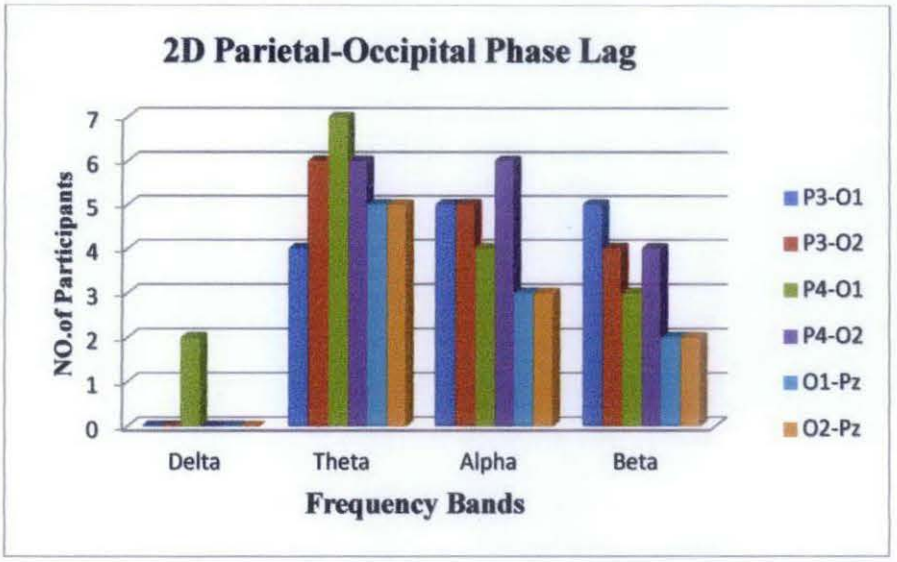


Figure 4.3: Difference of 2D and 3D Parietal-Occipital Coherence

Parietal – occipital relates in coordination between motor and visual system. Graphs above shows the coherence in Beta region is higher while playing in 3D mode in more number of participants compared to 2D, indicates that the amount of information shared by visual & motor parts while playing 3D is higher. In 3D mode, the visual part of brain struggles to perceives the unnatural depth projected by auto stereoscopic 3D of Nintendo 3DS at the same time participants also need to response to the game accordingly. These leads to huge information sharing between parietal-occipital lobes thus increase the load of brain while playing in 3D.

4.4 Phase Lag

Phase lag is the proximity of a two signals phase angle to zero, measurement the speed of information sharing



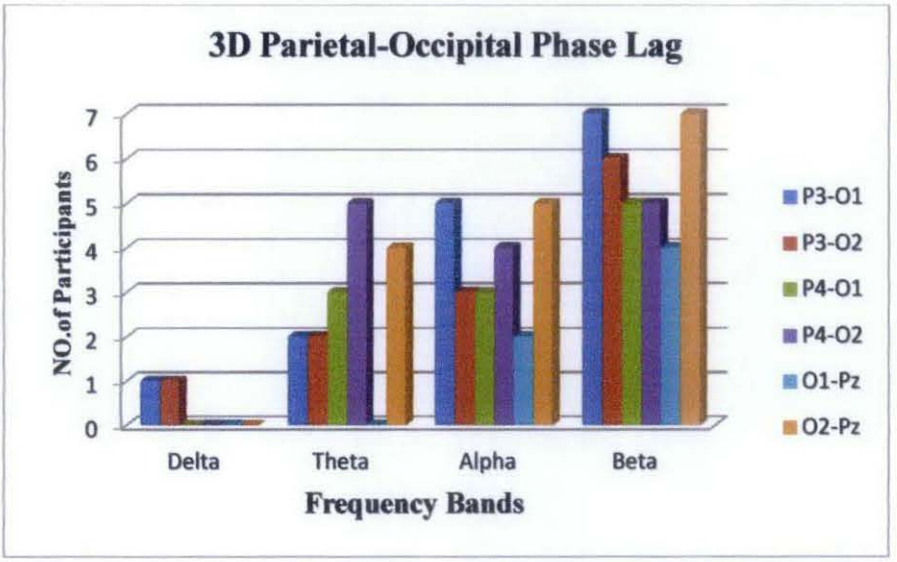


Figure 4.4: Difference of 2D and 3D Parietal-Occipital Phase Lag

From these two graphs, it is observed that speed of information sharing is higher in 2D in theta band and the information sharing is higher in 3D in Beta band. This suggests that 3D caused the parietal-occipital connection to be higher in order to see the depth of 3D game while at the same time trying to press the buttons of Nintendo 3DS (motor control).

4.5 Questionnaire Results

Below is the questionnaire results obtained from the 20 participants. The questions are about how they feel after playing 2D and 3D game of Nintendo 3DS.

Question/Respond	None	Slight	Moderate	Severe
1. Did you feel energized because of 3D?	5	6	7	2
2. Do you have general feeling of discomfort/ exhaustion because of 3D?	2	5	8	5
3. Did you feel better after playing the 3D video games?	7	4	5	4
	No	Maybe	Yes	Definitely
4a.Do you like 3D better than 2D video game?	6	5	6	3
4b. Will you want to play 3D games again?	7	5	4	4
4c. Would you encourage a learning technique that involves 3D?	3	4	7	6

Table 5: Questionnaire Results

From the questionnaire results, the participants prefer 2D mode compared to 3D mode of Nintendo 3DS. They also reported more moderate feeling of discomfort such as eye strain and dizziness after 20 minutes of playing 3D. This correlates with the EEG results that shows 3D caused more arousal and increase concentration level of participants.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions and Recommendations

Attention and concentration level increased when playing in 3D mode compared to 2D. In 3D, the brain requires more information sharing between visual and motor control region in order to response to the depth created. Presence of Beta waves in most of brain region is higher in 3D will lead to visual stress such as eye-strain and dizziness as the load of the brain is higher when playing in 3D. 2D mode of Nintendo 3DS is more relaxing and enjoyable compared to 3D mode.

It is recommended that Nintendo 3DS is better to be played in 2D mode compared to 3D. With small screen and unnatural auto stereoscopic 3D, 3D mode of Nintendo 3DS gives more mental load rather than pleasure of playing and will affect the visual system if being played for long period of time.

For future work, the data quality and can be optimized by conducting experiments upon controlled group in controlled environment. By controlling the daily supplements, food intake, sleeping hours and stress level of the participants, more accurate & less variation of data can be obtained as all the mentioned criteria affected the EEG signal of the participants.

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