Brain Signal Analysis while Watching Stereoscopic 3D Movies

by

Samar Mohammad Fawzy Adam Shahin

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical And Electronics Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

(Dr. Aamir Saeed Malik)

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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.

Samar Fawzy

SAMAR MOHAMMAD FAWZY ADAM SHAHIN

ABSTRACT

An electroencephalogram (EEG) is a test that measures and records the electrical activity of brain. Special sensors (electrodes) are attached to the head and hooked by wires to a computer. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. With technology growing every day, and stereoscopic 3D televisions becoming commercially available, a question arises: what kind of effect do 3D movies have on the brain activity and brain signals? The objective of this project is to have an attempt at answering this question as very little research has been done in this field. An EEG study was conducted on 30 healthy participants while watching a series of clips in 2D, stereoscopic 3D using active glasses and stereoscopic 3D using passive glasses. Their brain activity was recorded, and analyzed by writing a code in MATLAB to compare between the brain signals in terms of power, coherence and phase. We focused on the activity in theta and beta frequency bands. This paper shows that the results revealed a decrease in concentration in stereoscopic 3D compared to 2D, as well as higher learning behavior in 2D.

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Praise is to Allah, The Most Gracious and The Most Merciful for His endless blessings throughout my life and the success He granted me during my study and in my final year project.

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TABLE OF CONTENTS

List of Figures

List of Tables

Abbreviations

EEG	Electroencephalogram
3D	Three-dimension
2D	Two-dimension
TV	Television
PC	Personal Computer
BDA	Blu-ray disk Association
PS3	Play Station 3
F	Frontal
O	Occipital
P	Parietal

CHAPTER 1
INTRODUCTION

1.1 Background of the study

EEG, short for Electroencephalogram, is a medical test that measures the brain activity and records it while the subject is performing certain behaviour of concern. Hans Berger, a neuro- psychiatrist, introduced the EEG machine in 1929. He was the one who formulated the idea that the brain activity in the form of signals depends on the function performed by the person, i.e. what the brain is doing. He described the graphical representation of the electrical signals that represent the brain state using the German term *elektrenkephalogramm* [1]. Later on, this branch of science grabbed the attention of a wide range of scientists, doctors, and engineers. Nowadays, EEG has become a regular medical procedure to test for seizures, epilepsy, and other neural-related problems where the brain signals recorded during the EEG test are analyzed and interpreted by using special softwares that can give an accurate description of the brain state and if there are any deficiencies present or not.

Living in the 21st. Century, more tasks are created for the brain daily due to the great enhancement in technology. Watching stereoscopic 3D (three-dimensional) movies is one of these new tasks that did not exist before. It all started in 1894, when British film pioneer William Friese Greene filed a patent application for a mean to watch 3D using a stereoscope that merges two images coming from two adjacent screens. [2] A stereoscope is a device that creates the illusion of depth giving the 3D effect out of two 2-dimensional images. This is done by having each eye see only one of the two images and the brain processes this giving 3D effect. The film industry has vastly grown over the past few years as creators have been trying to provide a better experience while watching movies.

In this year, 2011, more than fifty stereoscopic 3D movies have been announced for release [3], thus the need to study the effect of 3D on brain activity rises.

1.2 Problem Statement

EEG tests can be performed to explore the brain activity that corresponds to a specific function carried out by the brain. As mentioned earlier, watching movies in 3D is becoming more and more popular and available. As 3D technologies is relatively recent, almost none or very little research has been conducted on the brain activity while watching stereoscopic 3D movies and comparing it to its counterpart while watching a normal 2D movies. And here comes the significance of this project as many questions are asked about how stereoscopic 3D affects the brain: does it require more concentration than that required in 2D? Could it have negative effects on the brain on the long run? These questions can only be answered by extensive research.

1.3 Objectives & Scope of study

This project is concerned with doing a research on a group of participants to study the effects of 3D movies on their brain signals using EEG.

The main objectives of this project are to:

1- Analysis of the collected data to compare between 2D and stereoscopic 3D using active glasses.
2- Analysis of the collected data to compare between 2D and stereoscopic 3D using passive glasses.
3- Comparing between the results obtained in 3D active and 3D passive to see the difference between the effects of both on the brain.

1.4 The Relevancy of the project

It is believed that this project is directly related to engineering as it is concerned with a field of engineering known as *Biomedical engineering*. Biomedical engineering is a field of engineering that combines biology to study diseases and other biology-related issues from the engineering point of view. This branch of science is based on analysing experimental data that is collected in order to understand living systems and to develop devices, methods and algorithms that advance biological

knowledge and can be extended further to help solve medical issues [4] .Here we are using EEG experiments to see how the brain will behave in response to 3D movies. Also, Brain activity is in the form of voltage pulses (signals), which is related to basic engineering concepts.

1.5 Project Feasibility

This project was trusted to be feasible as the equipment needed is available in the university laboratory. In addition, it is feasible with relevance to time as it is carried out on two semesters. This is further elaborated in the Methodology section, in chapter 3 sections 3.2 & 3.3.

CHAPTER 2
LITERATURE REVIEW

2.1 The Human Brain

The brain is the control centre of the human body. Any function that is done by any part of the body such as eating, moving, breathing and other biological functions, even thinking is done through the brain by transmitting and receiving a numerous number of signals in the form of hormones, nerve pulses, and chemical messengers. [5] The number of functions that can be executed by the human brain is countless; in fact they are in continuous increase.

2.1.1 Brain structure

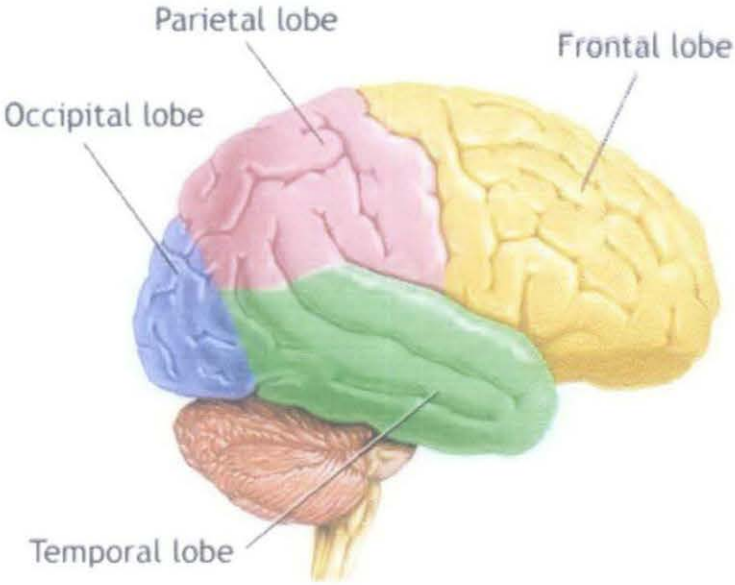


Figure 2.1: The human brain

The limbic system is a word used to describe a group of connected cortical structures that are involved in executing any sort of function done by the human. Figure 2.1 gives a summary of the human limbic system which is divided into [6]:

1- **Frontal Lobe:** this part of the brain is responsible for cognitive functions such as learning, creativity, responses, reasoning, emotions and problem solving.

2- **The Temporal Lobe:** It is divided into right and left side; the right side controls storing and retrieving memory, emotions, hearing, while the left side is responsible for language.
3- **The Parietal Lobe:** It is related with bodily functions that are related to senses such as temperature, taste in addition to calculating location and speed of objects.
4- **The Occipital Lobe:** The visual information is transferred from the eyes to the occipital lobe via the optical nerve where it is processed or transferred to other parts for storage or identification.

More interpretation of these parts is provided later in section 2.4 with relevancy to the project in hand.

2.1.2 Brain Signals

The neurons, or nerve cells, in the brain are constantly producing tiny electrical signals. These neurons are made up of three main components: cell body, dendrites (receivers) and axons (transmitter). A –70mV resting potential exists across the cell membrane. On the cell membrane there are ionic channels that are permeable to sodium (Na+) and potassium (K+) ions. These ions can polarize the membrane and fire an action potential that travels along the axon towards other neurons. The nerve impulse travels between axon and dendrite. Thus, processes in other cells are affected.

Information is transmitted by nerve cells in the form of electric signals in the body. Diffusion of ions as calcium, sodium, and potassium ions across the cell membranes create these electric pulses. When a person is doing any function, the concerned part of the brain is triggered. The electroencephalogram is a reflection of the current flow associated with the summed activity of many neurons. [7]

In 1924, Hans Berger the German neuro-psychiatrist was credited with recording the first human EEG. He formed electrodes out of metal strips and attached them to the scalp of his subjects. He used a sensitive galvanometer as the recording instrument. He noticed that the waves are in the range of (50-100) μV, and they follow certain periodicities, i.e. they are not random, but follow patterns and repetitions. [8]

Later in 1934 Adrian and Matthews published a paper verifying concept of "human brain waves" and specifically defined a group of waves that followed a certain pattern and named them "alpha rhythm". These waves range from 10 to 12 Hz [7]. The behaviour, of electrical activity recorded from the brain can be classified according to amplitude and frequency of the brain wave. [9]

Band	Voltage Range	Frequency	Comments
Delta (δ)	2-100 μV	0.5-4 Hz	dominant during deep sleep
Theta (θ)	80 μV	4-8 Hz	Dominant during drowsiness, meditation, and pre-sleeping.
Alpha (α)	50 μV	8-13 Hz	Dominant when person is awake, relaxed, closed eyes.
Beta(β)	20 μV	13-3- Hz	Dominant when activity is being carried out.

Table 2.1: a summary of EEG bands

2.2 EEG machine

An EEG machine set is used to collect data and store it for future display. The main components of the system are: electrodes, connecting wires, amplifiers, a computer for control, display and processing of the EEG data [1]. The number of channels that pick up the EEG signal is defined by the number of electrodes in the head cap in machine set used. The EEG uses amplifiers to upscale the weak signals from the brain into a readable signal for the output device. [1] After the experiment is conducted, and data is recorded, it is processed by using computer softwares to be able to study the brain signals and analyze them.

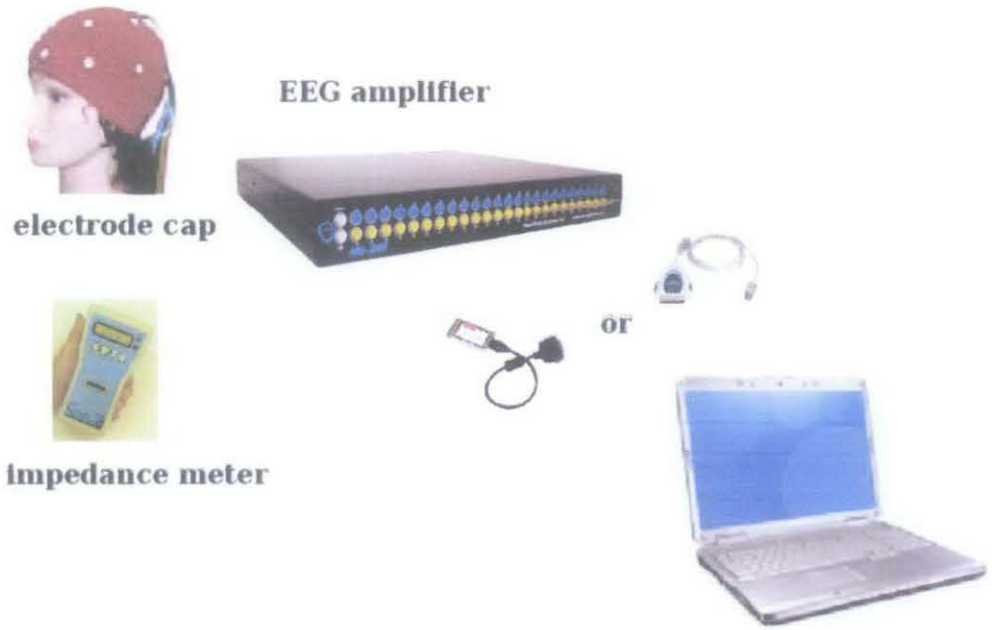


Figure 2.2: example of EEG machine set

Brain activity can be changed by medications or exposure to certain drugs. It has been proved that the brain activity of most of the patients with psychological problems and taking drugs will be affected. There are also a lot of substances that have an effect on the speed by which neurotransmitters fire as caffeine, heroin, and other antidepressants, and sedatives. In addition, personal habits like lack of regular sleeping habits, stress, body hormones can affect brainwave activity vastly. In addition, stress, religious devotion, and even cultural background have all shown to have some level of influence on how the brain functions. [10]

2.3 3D Technology

There are two aspects when talking about 3D; the first one is the device showing 3D (TVs, PCs, etc.) and the viewer. High-definition cameras are used to capture two different images instantaneously, the first camera focus on the left angle of an image and the second one focus on the right angle of the image. Next step is the image processing of both of the captured images, the processing makes the focus and depth of the two images compatible, and then they are converted into one 3D image via a processor.

Now coming to how the viewer can interpret the third dimension, this can be achieved by three methods:

1- Passive Glasses/ Anaglyph glasses: They use two different colours for each lens, one blue the other is red. There will be two images on the screen with a slight offset, one looking more "bluish" and the other more "reddish". The red lens filters the "more reddish" image out leaving the eye behind it seeing only the blue image and similarly the eye behind the blue lens sees only the red image. This makes the brain feel that it is seeing the normal 3D object, and gives the 3D effect. See figure below.

2- Active Glasses/ liquid-crystal glasses: These require synchronization with the TV, where the left eye will see the left eye image and the right eye will see the right eye image which are alternating at a very high speed giving 3D illusion.

3- No glasses/ auto stereoscopic: this requires integrating the lenses onto the screen, like in Nintendo games.

Compared to existing (2D) TV services, stereoscopic 3D-TV stresses much more the visual perception of human viewers. Indeed, technological choices made to deploy 3D-TV are leading to some challenging consequences that the human visual system (HVS) has to deal with. [3]

Figure 2.3 Passive Glasses

Figure 2.4 Active Glasses

2.4 Previous Research

It has been shown that some films can exert a control over brain activity and eye movements in a way that cannot be ignored. However, this cannot be generalized to cover all different types of movies and films, as there are many factors that affect the level of control over viewers' brain activity. An example of these factors is: movie content, editing, and directing style. [11]

We are mainly interested in the behaviour of visual attention, working memory and concentration while watching stereoscopic 3D movies.

A paper showed that more eye movements are involved when a person is watching a 3D movie. [12] There are two types of eye movement:

- fixation: eye is looking at a single location of the scene.(Occipital lobe is involved: information is gained)
- Saccades: eye is moving from one location to another. (Frontal Eye Field located in frontal lobe is involved).

The understanding of this shows that the increase in eye movements is because the person is trying to capture a lot of details in case of 3D compared to that in 2D or in other words, the eye movements are directed towards a wider array of objects in 3D movie than in a 2D movie. If a person is entirely looking at the actor in 2D, the same scene in 3D would include far more interesting details in 3D. The viewers' eye movements show them exploring these details.

This fact is supported by another research which pointed out that many non-gamers lose focus while playing 3D video games , they are more distracted or they don't pick up an important item because they don't notice it. [13] This implies the hypothesis that concentration decreases in stereoscopic 3D.

Attention Researchers have described two different ways in which our brains attend to items surrounding viewers [14]:

- Bottom-up processing: this is like a reflex action where one attends to the items whether we want to or not. In other words, the attention is driven by a

certain stimulus. Example for that is a weird irregular shape, where one is forced to attend to it. Parietal and Temporal cortices are involved.[15]

- This type of attention involves top-down processing: This is mostly powered by frontal cortex. [15] The viewer has the option to select what they want to look at, or in other words, the viewer attends to the object because they want to.

It has been shown that both bottom-up and top-down visual attention patterns exist within 3D video games. [14] Moreover, having previously discussed that there are far more eye movements in 3D clips compared to their counterpart in 2D, it is illogical to say that observations about visual attention made from the presentation of 2D stimuli can be automatically generalized to 3D.[3]

Another point to consider is the working memory at which the information that a person attends to is briefly stored for decision making and procession. The working memory gives a definition of the degree of strength of the information competing to access the memory. The parts of brain involved in working memory are related to the type of information of interest, for example, tasks related to verbal working memory activate the ventrolateral prefrontal cortex (PFC) and language areas in the temporal and inferior parietal cortex on the left side, while tasks related to visual working memory activate the dorsolateral PFC, inferior parietal cortex on the right side, and high-order visual areas in the occipital cortex. [16]Integrating this with the fact that there is more visual attention in 3D makes us expect more activity in the prefrontal cortex as well as the occipital cortex, even more than the activity present in case of 2D.

It was found that there will be an increase in theta activity with task difficulty, which consequently suggests that this signal might be related to the mental load allocated to task performance. However, alpha activity was found to decrease with increased mental load. [17]

Keeping in mind that theta waves are associated with pre-sleeping, learning, or highly creative states, or in other words it is related to states of minimal concentration, means that theta increases when concentration decreases. Considering

Beta waves, they are associated with high level of concentration, thinking, learning, in other words, beta increases when a mental task is being carried out. [18]Since concentration is expected to decrease in 3D, beta activity is expected to decrease.

Thus, to summarize our hypothesis:

1- Concentration is less in 3D therefore theta waves will be more in 3D than in 2D.
2- Beta waves are expected to be higher in 2D than in 2D.
3- More activity is expected in the prefrontal cortex as well as the occipital cortex in case of 3D.

It is worth mentioning that a study showed that people are pay more attention by 12% when watching Blu-ray 3D compared to a regular Blu-ray disc and 29 per cent more attentive when that same 3D experience is up against a plain old DVD. [19] This study was assigned by the BDA (Blu-ray disk Association), which indicates that the association is hoping for a result that shows that 3D is better than 2D and that Blu-ray is better than DVD. [19] However, the fact that they used 24 participants only does not really assert that.

More research needs to be done in these fields to provide a solid ground that can be used to answer the question of whether 3D has negative effects on brain activity or not. This project is concerned with that, where experiments will be conducted using a template described in a research paper testing brain activity during video game play. [17]

CHAPTER 3
METHODOLOGY

3.1 Methodology

As elaborated earlier, in this project, we will be conducting experiments to study how the brain behaves while watching 3D movies and compare it to 2D movies.

The project lifecycle is represented in the following simple flowchart:

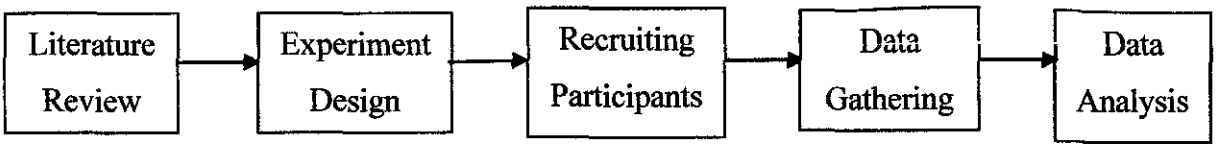


Figure 3.1: Methodology Flowchart

3.1.1 Data Gathering

1- Participants were recruited and those who do not match specific criteria according to the questionnaire attached in the Appendix I were filtered out. People who wear braces, take medications, or have any health problems were excluded as according to literature these things have an effect on the brain activity. People with skin allergies were excluded as we used using a certain type of gel that enhances the skin conductivity which could cause allergy. Healthy participants were included.

2- After recruitment, we proceeded with the experiments; we had two groups of 15 participants each. Group A watched the clips in the following sequence: 2D, 3D using active glasses, and then 3D using passive glasses. The other group (group B) watched 2D, 3D using passive glasses and finally 3D using active glasses. The purpose for that was to see whether there will be any difference in the results between the 2 groups. The duration for each type of viewing was 20 minutes, giving a total of 60 minutes, or one hour, which is approximately as long as a regular movie. The sequence of the experiment conducted is as follows

1. Setting up the experiment, applying the cap to the participant, as well as the electrodes and all sensors required. Participant is asked to sign a consent form that has the detailed experiment procedures in it as in appendix IV.
2. Eyes-closed Test. (for 5 minutes: the participant is asked to sit straight, not move, try to remain as stationary as possible, and close their eyes. The purpose of this is to see how the brain signals of a certain participant look like when he/she is totally relaxed).
3. Eyes-open Test. (for 5 minutes: same conditions like eyes-closed test with the exception that the participants are asked to open their eyes and concentrate on a simple stimulus: a black circle on a white board. This is to see how the brain looks like in a normal eye-open condition.)
4. 2D clips. (20 minutes)
5. Break. (5-10 minutes: for the participant to relax, get comfortable also fill up some forms as in Appendix).
6. Eyes-open test again. (5 minutes, this helps to minimize the learning and memory effect).
7. 3D (20 minutes: First type of glasses).
8. Break. (5-10 minutes).
9. Eyes-open test again. (5 minutes)
10. 3D (20 minutes: second type of glasses).

Figure 3.2: Data acquisition flowchart

A set of instructions were given to the participants in a briefing held by the research group as follows:

1) Participants were advised to have dry, freshly washed hair on the day of experiment. It is recommended to use only basic shampoo while washing the hair no conditioners, rinses, mousses, oils, hair sprays or any styling products applied on it.
2) Participants were asked not to put on any makeup and to keep their body free from any oils, lotions, and moisturizers.
3) Participants were advised to eat as normal, but avoid caffeine products, such as coffee, tea, soda pop and chocolate.
4) Participants were asked not to wear any earrings, hair ties or clips.

After data gathering, data processing and analysis stage was proceeded with in order to decide on an approach to achieve the mentioned objectives.

3.1.2 Data Analysis

The Data Analysis stage was divided into two sub-stages:

3.1.2.1 Pre-Processing/ Data Cleaning:

In this stage, the data obtained from the experiments is cleaned using Neuroguide software. Data cleaning means removing the "undesired" signals to obtain data that is noise-free. In brain signals, noise is defined to be signals that result from the body performing other functions that are not desired or are not of the study concern like eye-blinking, eye-rolling, clenched teeth, or any other abnormal muscle ... etc. Another reason could be the electrode impedance during EEG recording, which can be affected by skin conditions like sweat or skin thickness. Also, another source of artefacts is the main power supply when electrodes can pick up 50 Hz signals from the power supply.

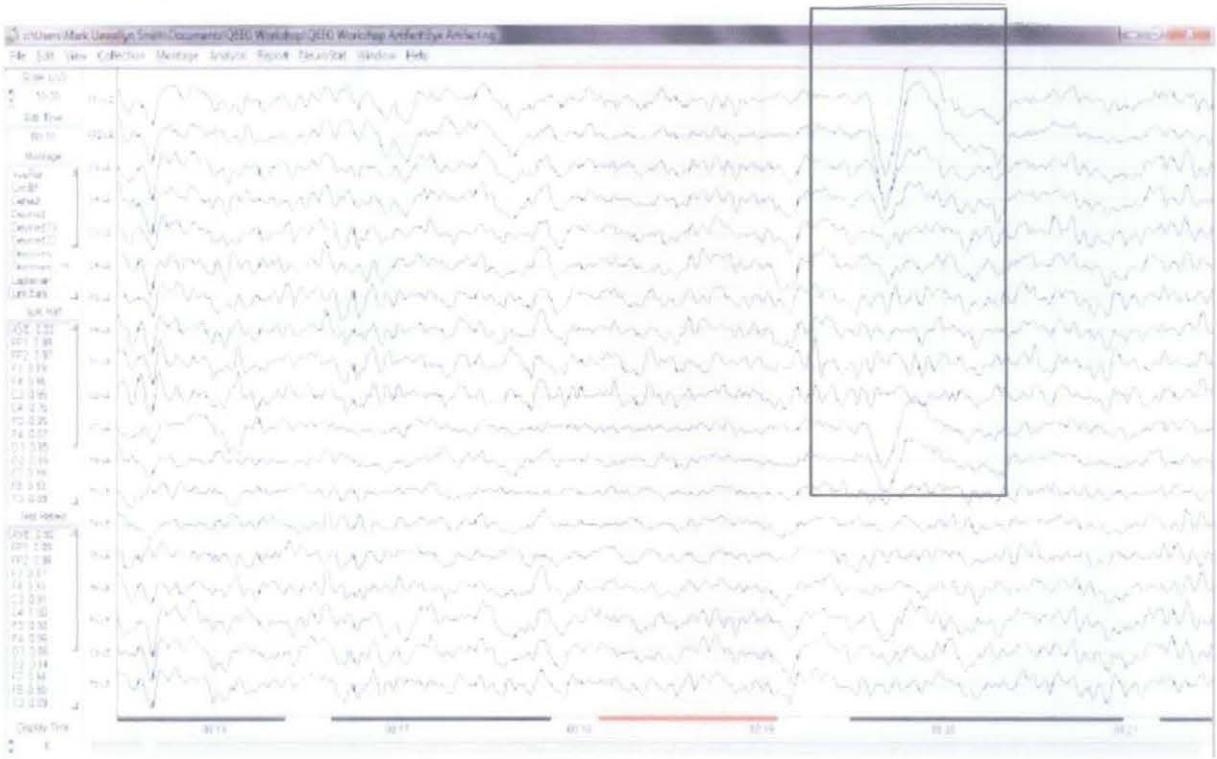


Figure 3.3: Eye-blinking artifact.

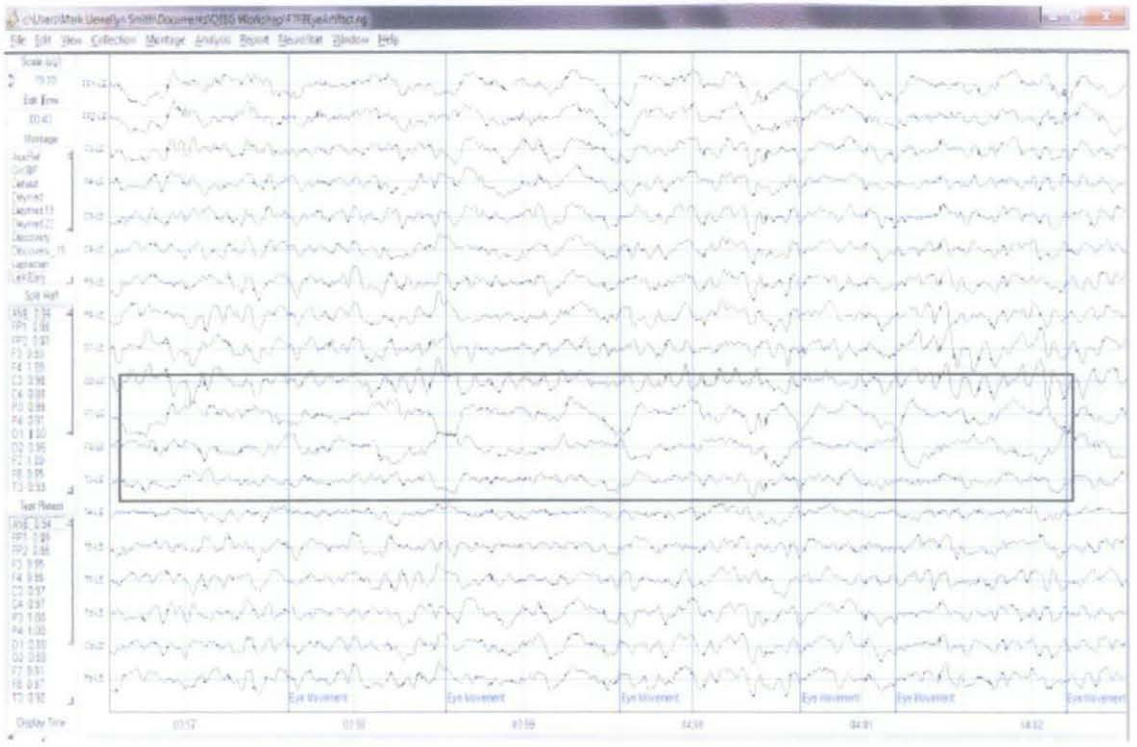


Figure 3.4: Eye-movement artifact.

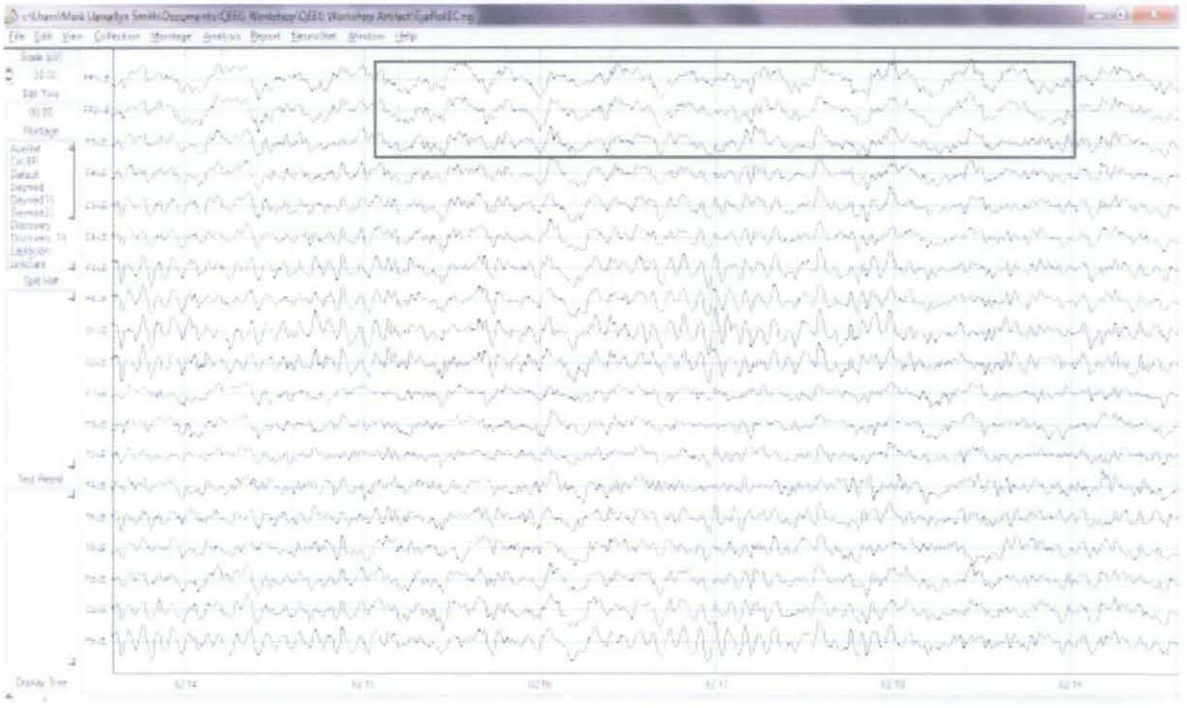


Figure 3.5: Eye-rolling artifact.

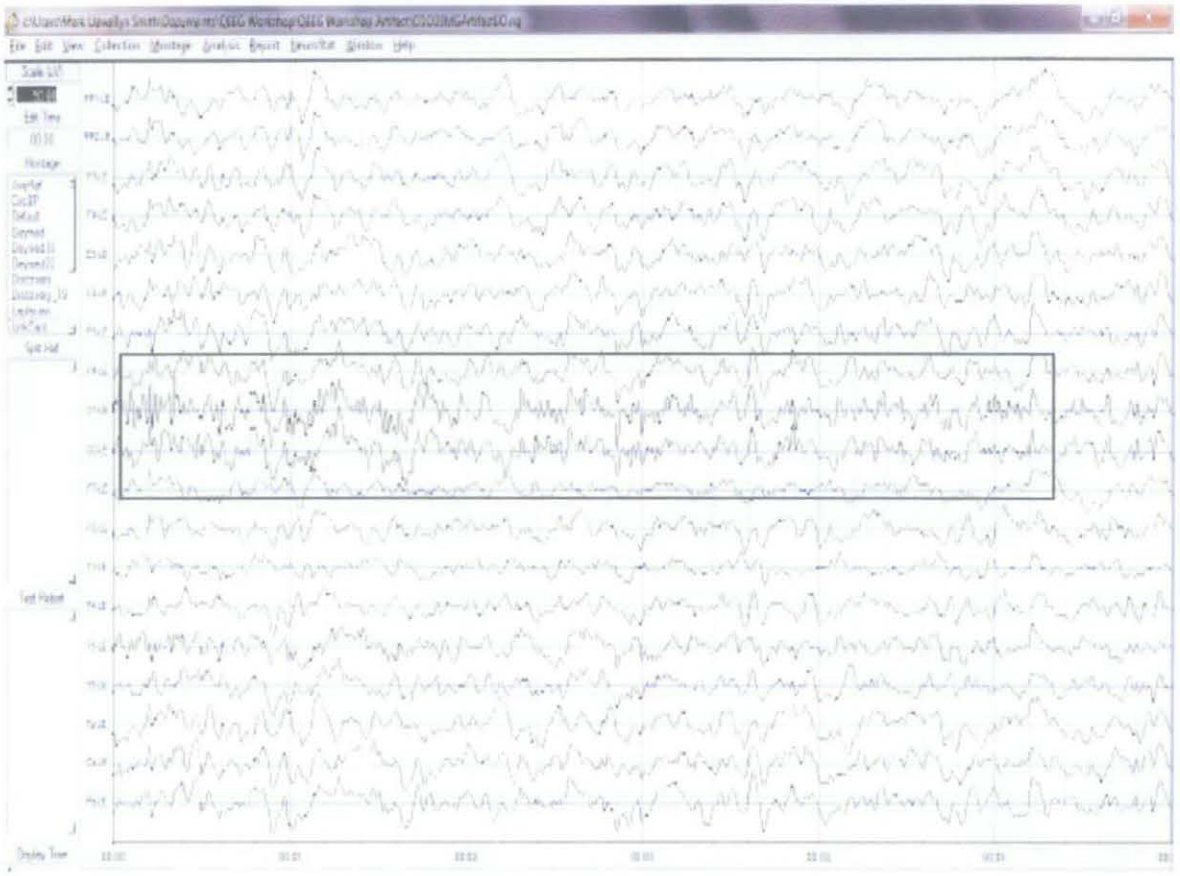


Figure 3.6: muscle artifact.

Data cleaning is done by scrolling through the recorded data of each participant and selecting parts that are free from artefacts and drowsiness. 1 minute of clean EEG data was selected in each of the 6 sessions in each type of viewing.

The brain activity, in the form of signals, is categorized according to their frequencies into the known EEG bands. Then, some terms are defined in order to be able to describe the signals (activity) of the brain.

1. Absolute Power: is measured as $P=V^2/R$, where V is the absolute voltage measured at the electrode.
2. Coherence: It reflects the amount of shared information (connectivity) between brain regions (any 2 electrodes). The brain regions could be Hyper or Hypo active.

$$Coh_{xy} = \left|R_{xy}(f)\right|^2 = \frac{\sum_i \left((x_i - \bar{x})(y_i - \bar{y})^T\right)}{\sum_i (x_i - \bar{x}) \sum_i (y_i - \bar{y})}$$

3. Phase: It defines the speed of information sharing between regions (any 2 electrodes). Phase Lag means slow speed (compared to normal people) and is assigned a red colour on the brain topo map. Phase lead means high speed and is assigned blue colour on the brain topo map.

All these terms are defined relative to a normative data base (comparing the participant with the scale of normal people to know how normal a person is) giving z-scores that quantify how many standard deviations the measurement is far from the mean. For example, Coherence compares the actual signal between 2 electrodes with the original signal from the data base (how the signal should normally look like) with respect to wavelength and whether they are in phase or not. The z-score is then assigned a colour as shown in figure 4.3. Phase compares the signal with its counterpart in the normative data base from the point of view of how shifted they are from each other (lagging or leading).

$$Z - score = \frac{measurement\ - mean}{standard\ deviation}$$

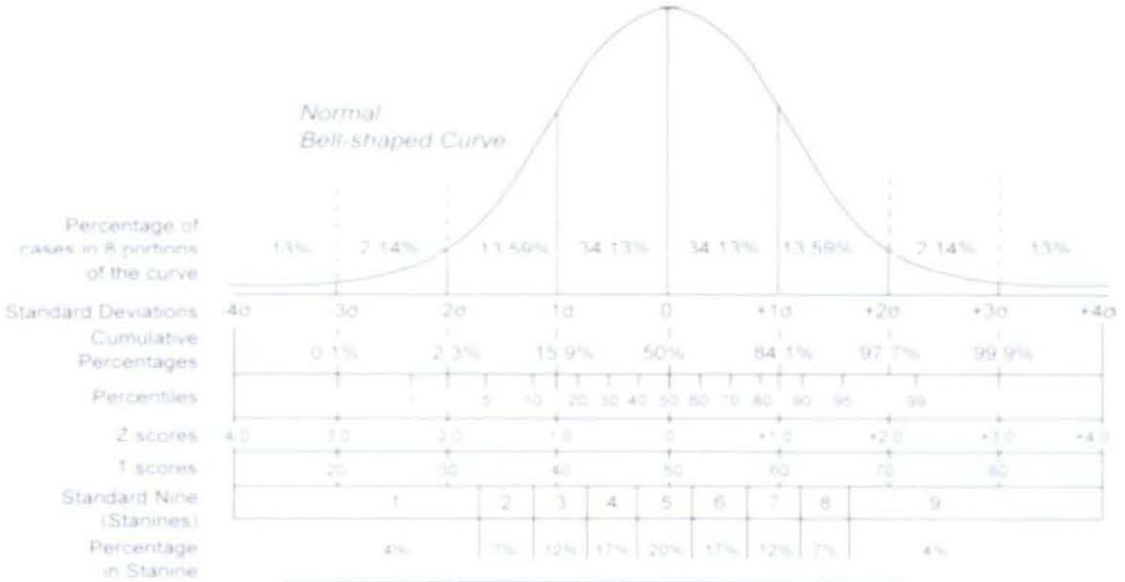


Figure 3.7: Normal Distribution curve.

Z-score ranges:

- +/- 1 sigma:

– Includes middle 68% of population

– From 16% to 84% points

- +/- 2 sigma:

– Includes middle 95% of population

– From 2% to 98% points

- +/- 3 sigma:

– Includes middle 99.8% of population

– From .1% to 99.9% points

- +/- 4 sigma:

– Very Abnormal

The Neuroguide software uses a normative data base that is based on 600++ normal people, with ages ranging from 2-82 and was approved by Food and Drug Administration in United States of America. A report is produced for each participant that contains the z-scores numbers and topo maps of the participant in different EEG frequency bands.

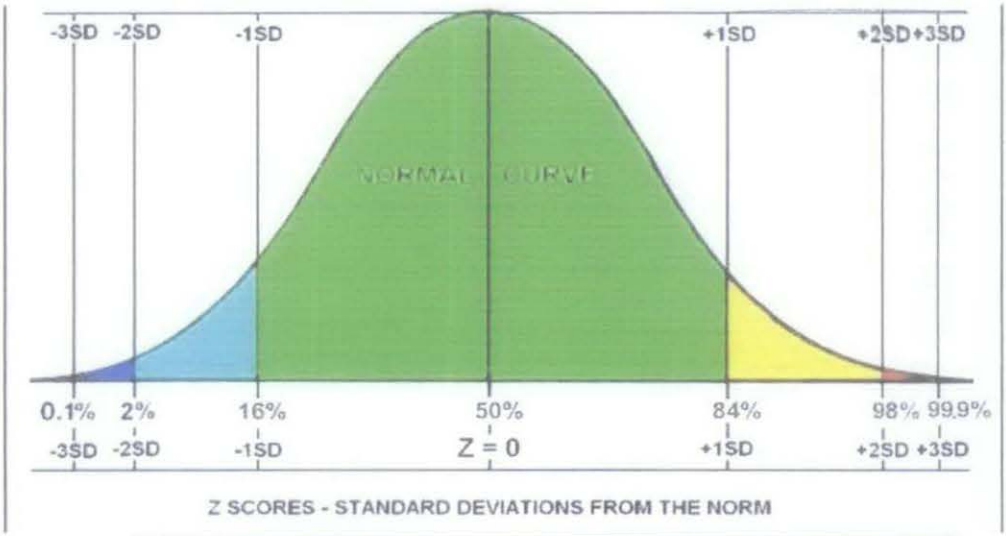


Figure 3.8: colors assigned to z-score values in Neuroguide

3.1.2.2 Analyzing the data:

Having cleaned the data, there are 6 minutes of clean EEG that was recorded while the participant was watching 2D clips, 6 minutes of clean EEG that was recorded while the participant was watching 3D clips using active glasses, and 6 minutes of clean EEG that was recorded while the participant was watching 3D clips using passive glasses. The analysis will be done as follows in 4 steps:

1. Using The Neuroguide Report-generating tool, reports were generated for each session (minute).
2. The z-scores of the 6 sessions in each type of viewing were averaged to get one session, so now we have 3 sessions for each participant. Participants are divided into 2 groups of 15 as mentioned earlier. Group A watched in the sequence: 2D-3D Active- 3D Passive and Group B: 2d- 3D Passive-3D Active. One participant's data was ignored from group A because the data was very corrupt as there was an amplifier problem. Because our analysis is concerned with seeing the difference between 2D and 3D, Neuroguide reports only provide z-scores for each session type, so it does not match with our requirements.
3. Due to the Neuroguide reports' limitations, we had to write some functions in MATLAB, according to the tables below. As per the attached appendix IV, the values of Absolute power, Coherence & Phase lag of 2D are compared to those of 3D active and 3D passive to determine which has more power, which is more hyperactive, and which requires faster information sharing. A threshold of 0.3 in coherence and 0.7 in phase was put based on trial and error, because we wanted to focus on the values that showed really big deviation from normal as elaborated in tables 4.1 - 4.3 & figures 4.8-4.12.

Sign of 2D z-score value	Sign of 3D z-score value	Output function	Output sign
+	+	3D - 2D	• If + then 3D>2D, 3D is on the RHS of the normal curve. • If - then 3D<2D, 3D is on the RHS of the normal curve.
+	-	3D - 2D	• Always +, 3D>2D, 3D is on the RHS of the normal curve.
-	+	3D - 2D	• Always -, 3D<2D, 2D is on the RHS of the normal curve.
-	-	3D - 2D	• If + then 3D>2D, 3D is on the LHS of the normal curve. • If - then 3D<2D, 3D is on the LHS of the normal curve.

Table 3.1: Absolute Power Function Table

2D z-score value	3D z-score value	Output function	Output sign
>0.3	>0.3	3D - 2D	• If + then 3D more hyper active than 2D • If - then 2D is more hyper active than 3D
<0	>0.3	3D	• 3D more hyperactive
>0.3	<0	-2D	• 2D more hyperactive
<0	<0	0	• Both 3D & 2D are hypo active, we are not interested in this case.

Table 3.2: Coherence Function Table

2D z-score value	3D z-score value	Output function	Output sign
>0.7	>0.7	3D - 2D	• If + then information sharing in 2D is faster. • If - then 3D is faster.
<-0.7	>-0.7	2D	• 3D is faster
>-0.7	<-0.7	-3D	• 2D is faster
<-0.7	<-0.7	3D-2D	• If + then Information sharing is faster in 2D • If - then Information sharing is faster in 3D
else	else	0	• Not interested

Table 3.3: Phase Function Table

After obtaining the values for each participant in the 2 groups, the output functions of absolute power, coherence and phase were plotted to see the results as shown in chapter 4.

3.2 Gantt Charts

em	1	2	3	4	5	6	7	8	9	10	11	12	13	14
roposing the pic														
iterature eview														
relim. Report ıbmission						✹								
articipants ecruitment														
EG Training														
ata gathering : Experiments														
ıterim report ıbmission														✹

Figure 3.9: Gantt chart for FYP 1

m	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ıta Analysis														
ɔgress report 1														
ɔmission														
d testing of the														
vice														
ɔgress report 2														
ɔmission														
ster exhibition														
ssertation														
ɔmission														
al presentation														
Project														
dissertation														
submission														

Figure 3.10: Gantt chart for FYP 2

Legend :

Deadline

Current progress

Future progress

3.3 Equipment & Tools

Equipment needed is available in the university Laboratory. We are using the following:

1- 10-20 EEG system: where the metal electrodes are attached on the scalp in specified positions. This is done by taking measurements between certain fixed points on the head. The electrodes are then placed at points that are 10% and 20% of these distances as shown in figure below. The electrodes are named using a combination of a letter and a number; the letter corresponds to the area of brain where the electrode is placed (F: Frontal lobe, T: Temporal lobe, O: Occipital lobe, P: Parietal lobe) and the number corresponds to the side of the brain where the electrode is put (even number: right side, odd numbers: the left side). This system was called the "10" and "20" as the distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull.

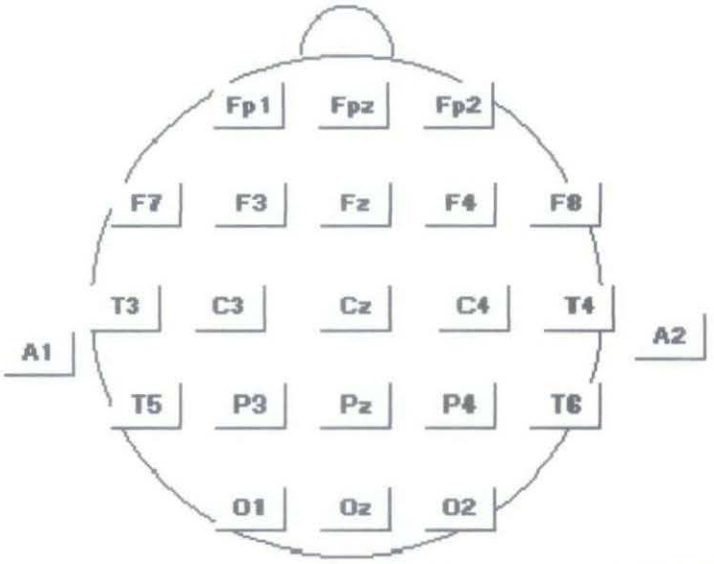


Figure 3.11: 10-20 EEG system

2- Laptops to record the signals during the session.

3- 2 3D TVs & PS3.

4- Neuroguide, Brain Master Discovery, & MATLAB softwares.

CHAPTER 4
RESULT & DISCUSSION

As mentioned in chapter 3 section 3.1.2.2, after obtaining the values for each participant in the 2 groups for the output functions of absolute power, coherence and phase, they were plotted. An example for one of the participant in group A is as follows: the figures can be interpreted using the tables in section 3.1.2.2.

Figures 4.1 & 4.2 show difference between 2D and 3D Active. Positive values indicate that 3D>2D while negative values show that 2D is greater.

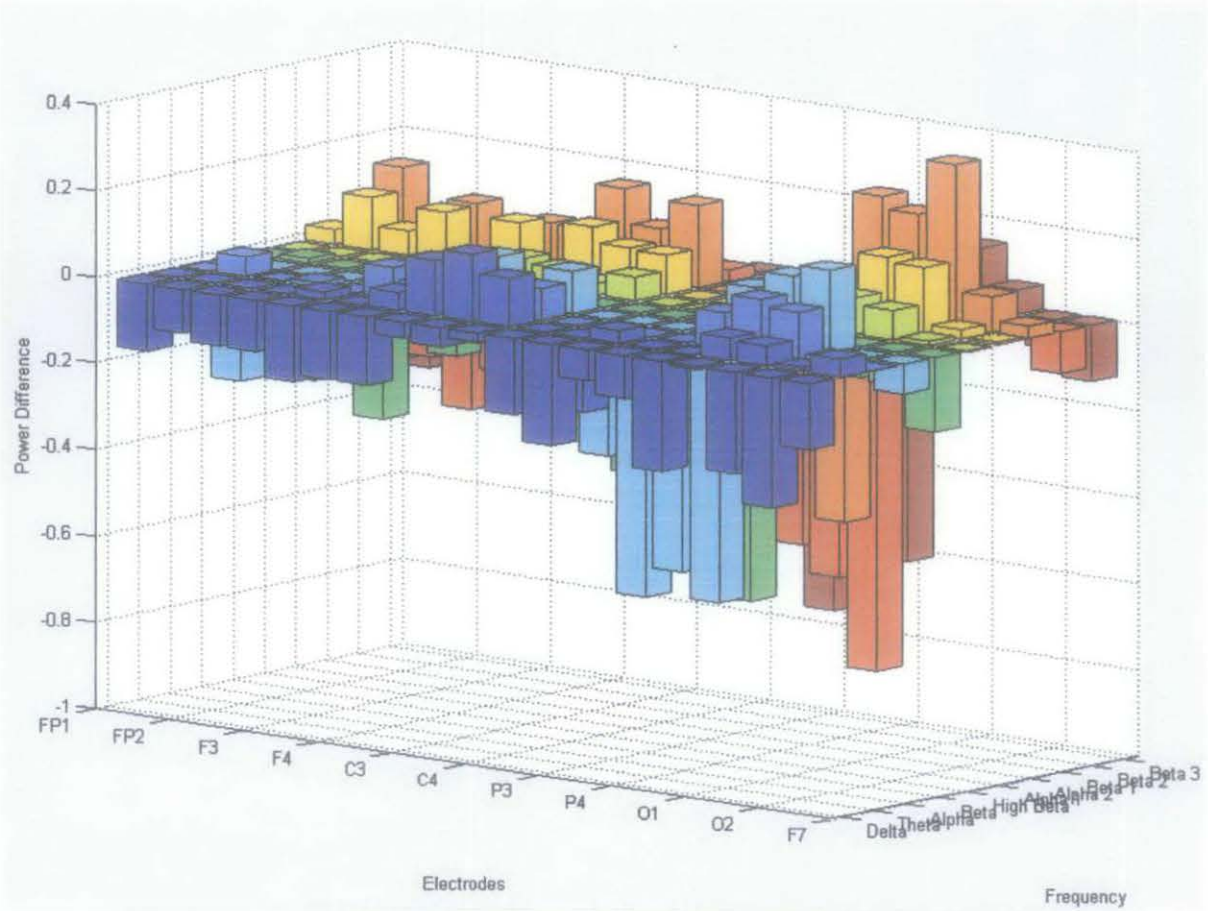


Figure 4.1: Absolute power difference between 2D & 3d Active

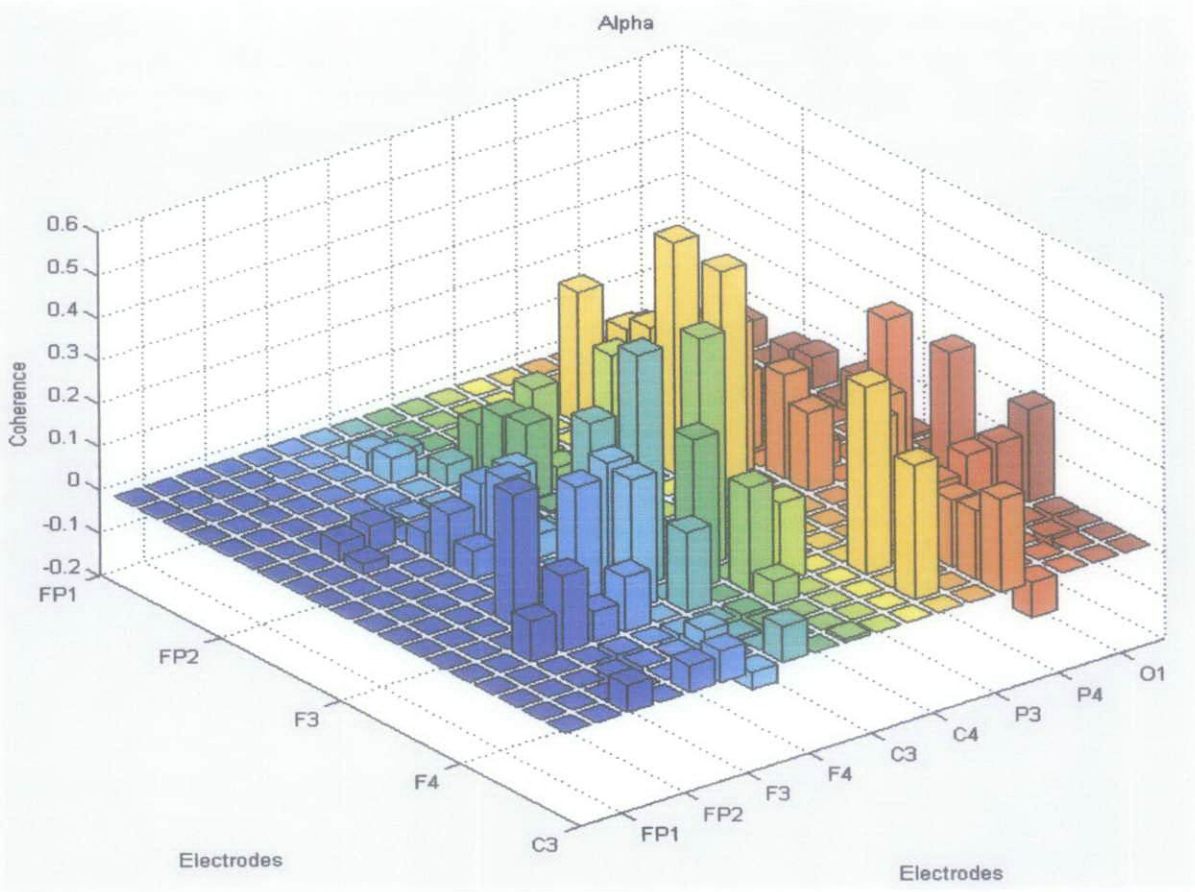


Figure 4.2: Coherence difference between 2D & 3D Active in Alpha frequency band

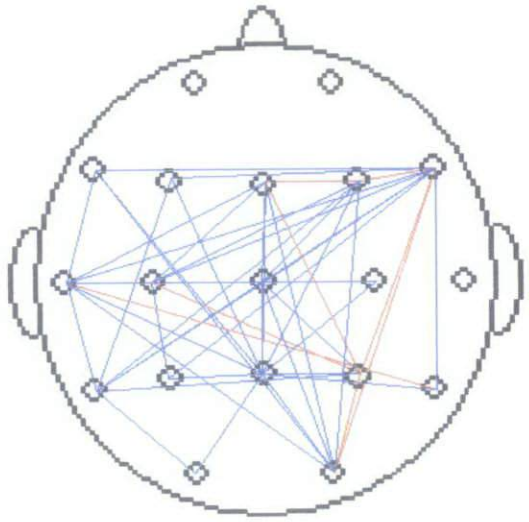


Figure 4.3: Coherence difference map between 2D & 3D Active in Alpha frequency band.

Blue lines show values where 3D coherence is higher between electrodes while red lines show values where 2D is higher.

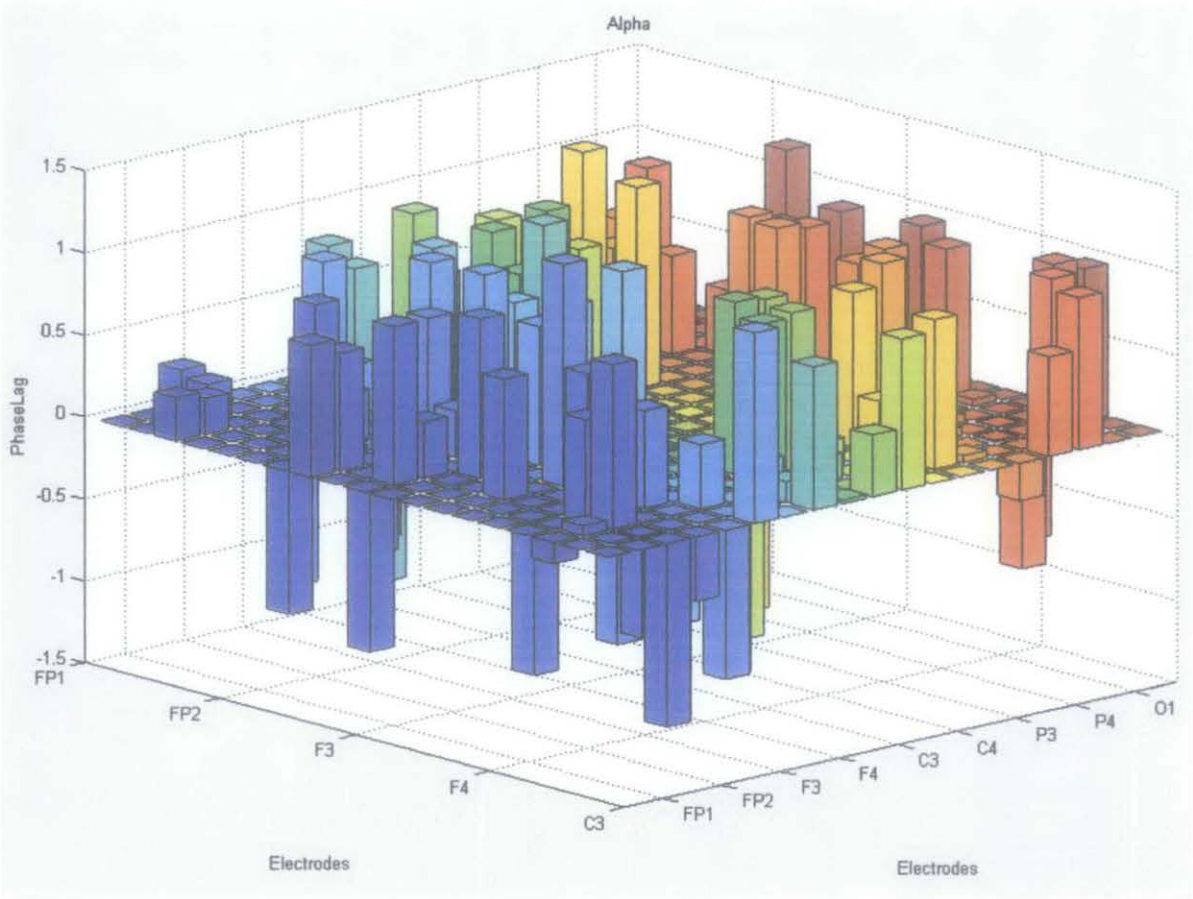


Figure 4.4: Phase difference between 2D & 3D Active in Alpha frequency band

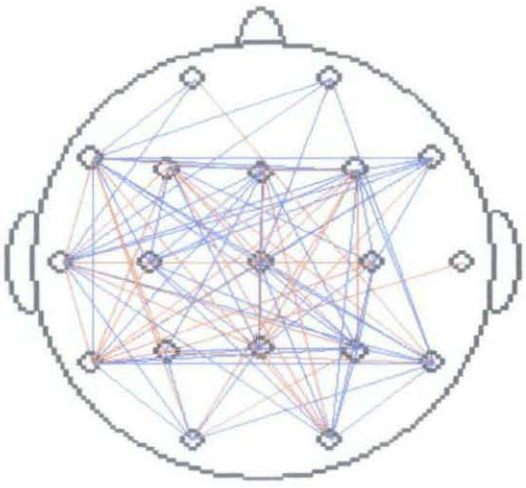


Figure 4.5: Phase difference map between 2D & 3D Active in Alpha frequency band.

Blue lines show values where information sharing in 3D is faster between electrodes while red lines show values where 2D is faster.

Next step in interpreting the results was to focus on the electrodes that are associated in viewing, memory and concentration which are Occipital, Frontal & Parietal, as well as the basic frequency bands which are Delta, Theta, Alpha, and Beta. We wanted to know how many times it was repeated in the two groups that these electrodes in these frequency bands showed more power in 3D or in 2D. The outputs of the functions of absolute power, coherence and phase for each participant were imported into an excel sheet. The electrodes which are not of concern were removed. In absolute power we focused on Occipital electrodes (O1, O2). In information sharing or Coherence we focused on the connectivity between Occipital-Frontal, Occipital-Parietal and Frontal-Parietal. The values of which 3D was greater were counted in each participant as well as 2D, and then the total number of participants was counted in each frequency band to see whether 2D or 3D was greater. See Appendix V for more of the graphs for coherence and phase.

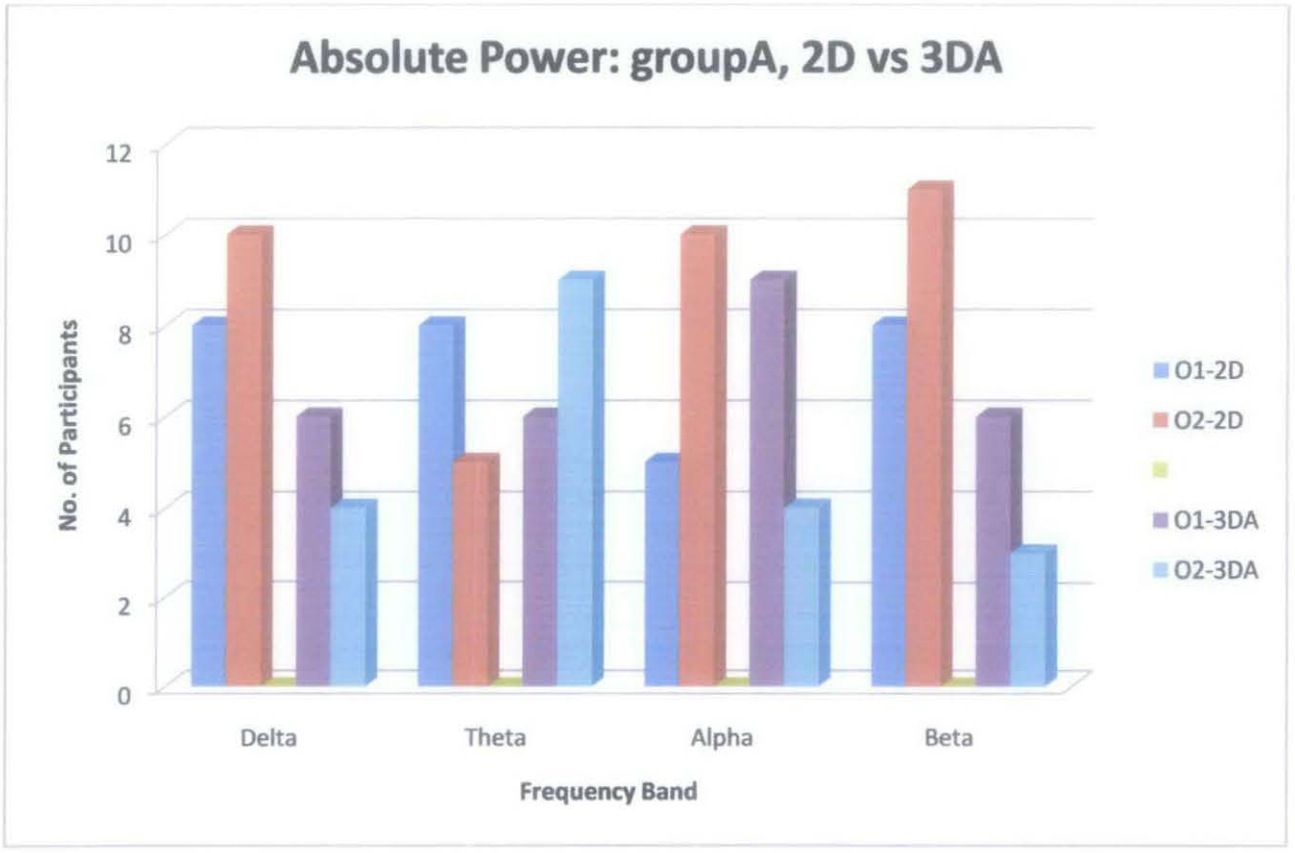


Figure 4.6: Absolute Power 2D vs 3DA in O1, O2

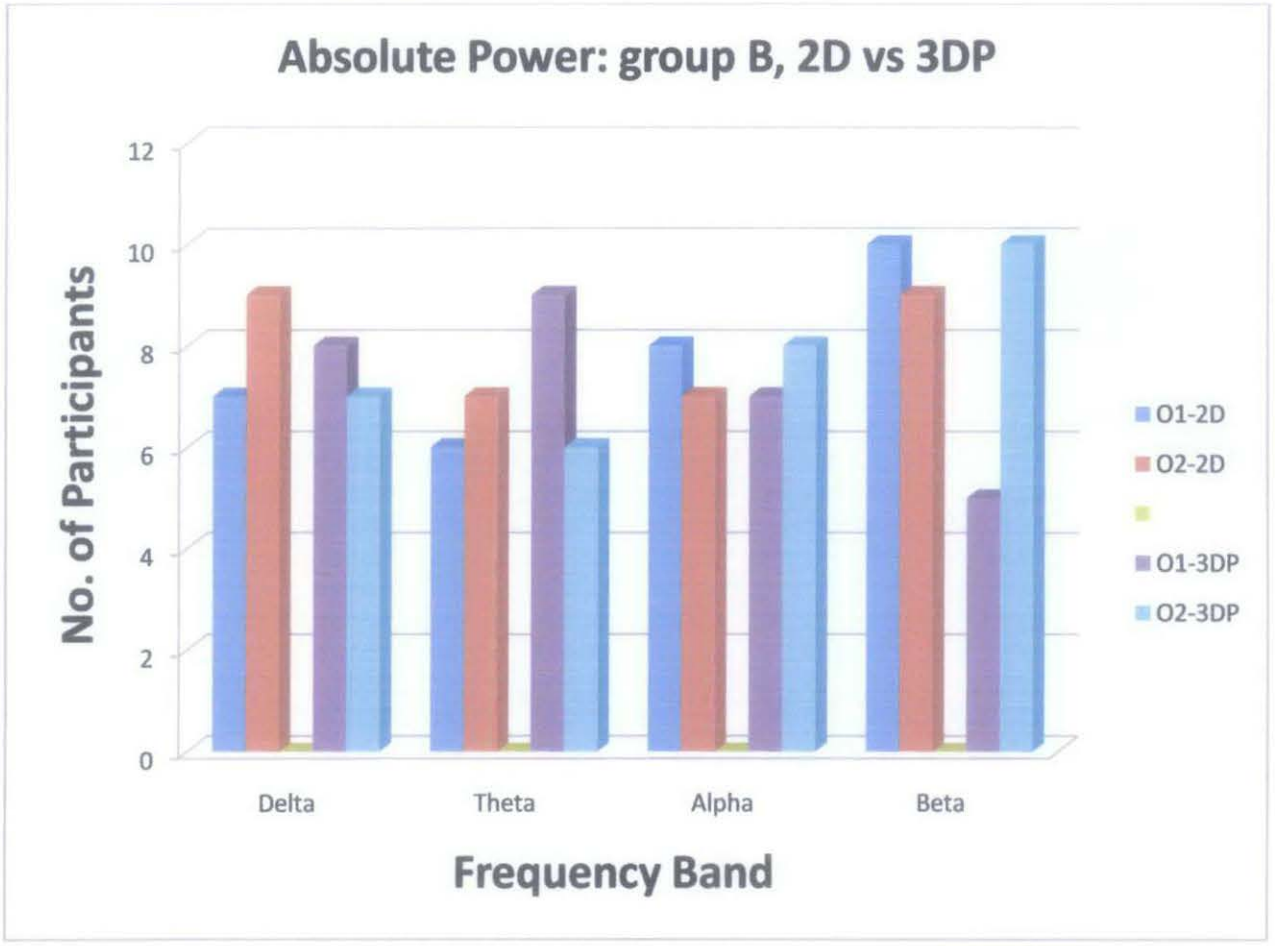


Figure 4.7: Absolute Power 2D vs 3D Passive in O1, O2

From the graphs, we could see that for the first two sessions (2D vs 3DA in group A & 2D vs 3DP in group B) for absolute power:

Band	Group A (2D vs 3DA)	Group B (2D vs 3DP)
Delta	2D	2D
Theta	3DA	3DP
Alpha	2D (1 participant difference)	same
Beta	2D	2D

Table 4.1: Absolute Power in Bands

For coherence:

	group A(2D vs 3DA)			group B (2D vs 3DP)		
	f-o	f-p	p-o	f-o	f-p	p-o
Delta	3DA	3DA	3DA	3DP	3DP	3DP
Theta	3DA	3DA	3DA	3DP	same	3DP
Alpha	2D	2D	3DA	same	2D	2D
Beta	2D	2D	3DA	2D	same	2D

Table 4.2: Coherence in Bands

For phase:

Band	group A (2D vs 3DA)			group B (2D vs 3DP)		
	f-o	f-p	p-o	f-o	f-p	p-o
Delta	3DA	3DA	2D	2D	2D	2D(one participant difference)
Theta	3DA	3DA	3DA	2D	3DP	3DP
Alpha	3DA	3DA	3DA	same	2D	3DP
Beta	2D	3DA	2D	3DP	2D	2D

Table 4.3: Phase in Bands

Coherence	f-o	f-p	p-o	Phase	f-o	f-p	p-o
Delta	3DP	3DP	3DA	delta	3DA	3DA	3DP
Theta	3DA	3DP	3DP	theta	3DA	3DP	3DP
Alpha	3DA	3DP	3DA	alpha	3DA	3DA	3DA
Beta	3DA	3DA	3DA	beta	3DP	3DP	3DA

Table 4.4: 3DA vs 3DP

Knowing that delta is related to deep sleep, we will ignore it for time being. However, looking at Theta we can see that more participants showed that power was greater in 3D than in 2D in both groups, integrating this with the fact that theta increases when concentration decreases, this shows that concentration was less in 3D. Looking at alpha, they are almost the same.

Looking at beta, we can see that more participants showed that power was greater in 3D than in 2D in both groups, and knowing that beta is related to learning and concentration, and since concentration is less in 3D, and since the participant was seeing the clips for the first time in 2D, it shows that the first-exposure in 2D required more power to learn at the occipital electrodes. Beta being higher in power in 2D in Occipital regions could mean that the participant experiences more fixations than in 3D.

Considering Coherence, alpha being mostly higher in 2D could imply that the brain is more relaxed in 2D, this doesn't contradict with the increased focus, the brain is more relaxed because 2D is not something new to it.

Theta band showed higher connection in 3D which again could mean that the concentration is less, that is why more electrodes are trying to communicate with each other to process the large scale of information. 3DP mostly showed higher connection than 3DA which might mean that concentration was less in 3DP than in 3DA. This agrees with the participants' feedback -to the questionnaire in Appendix II shown in table 4.11 and figure 4.15 below- that indicated that 25 participants out of 29 said they prefer 3D passive to 3D active as the 3D effect is nicer in case of 3D passive, or in other words there are more details to process.

Coherence in Beta again appeared to be mostly higher in 2D. Coherence in Beta and Alpha being higher in 2D except in Parietal-Occipital electrodes in group A, and having established the fact that tasks related to visual working memory activate the dorsolateral PFC, inferior parietal cortex on the right side, and high-order visual areas in the occipital cortex, could give an indication that 3D information has higher ability to compete and gain access into working memory.

Moving to phase lag, again theta was mostly higher in 3D, which means slow rate of information sharing or could assert the less concentration and beta mostly higher in 2D.

Recalling that for group A, 3DA was the 2nd session, and for group B 3DA was the third session, and similarly for group B 3DP was the 2nd session while 3DA was the third session, we did a comparison to see if there will be any deviation in the results from the original (tables 4.5- 4.7). Similar tables were constructed for the passive sessions. Very little deviation was found which does not contradict with the conclusions mentioned previously.

Absolute Power

	3DA 2nd session	**3DA 3rd session**
Delta	2D	2D
Theta	3DA	2D
Alpha	2D (1 participant difference)	2D
Beta	2D	2D

Table 4.5: Absolute power, 3DA 2nd session vs 3DA 3rd session

Coherence:

3DA first session				**3DA second session**		
	f-o	f-p	p-o	f-o	f-p	p-o
Delta	3DA	3DA	2D	3DA	3DA	3DA
Theta	3DA	3DA	3DA	3DA	2D	3DA
Alpha	3DA	3DA	3DA	3DA	2D	2D
Beta	2D	3DA	2D	2D	2D	3DA

Table 4.6: Coherence, 3DA 2nd session vs 3DA 3rd session

Phase:

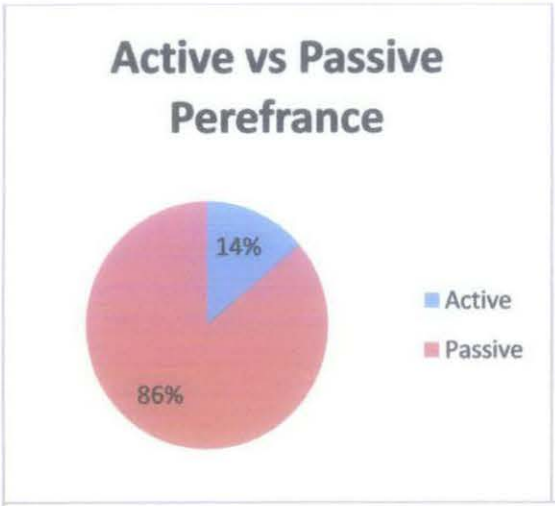
3DA first session				**3DA second session**		
	f-o	f-p	p-o	f-o	f-p	p-o
Delta	3DA	3DA	2D	2D	3DA	2D
Theta	3DA	3DA	3DA	3DA	3DA	3DA
Alpha	3DA	3DA	3D A	2D	2D	3DA
Beta	2D	3DA	2D	2D	2D	2D

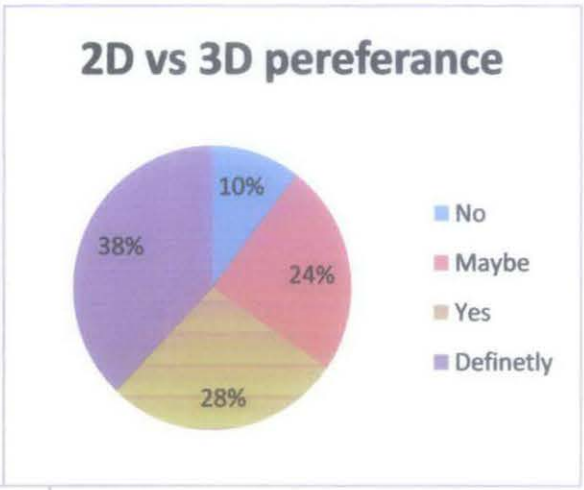
Table 4.7: Phase, 3DA 2nd session vs 3DA 3rd session

It was previously mentioned that 3DP mostly showed higher connection than 3DA which might mean that concentration was less in 3DP than in 3DA. This agrees with the participants' feedback -to the questionnaire in Appendix II shown in table 4.8 and figure 4.8 below- that indicated that 25 participants out of 29 said they prefer 3D passive to 3D active as the 3D effect is nicer in case of 3D passive, or in other words there are more details to process.

1	None	Slight	Moderate	Severe
	5	14	8	2
2	None	Slight	Moderate	Severe
	9	12	7	1
3	None	Slight	Moderate	Severe
	7	9	10	3
4a	None	Slight	Moderate	Severe
	2	5	12	10
4b	No	Maybe	Yes	Definetly
	0	6	6	16
4c	Natural	Buildings	people	other
	18	3	8	1
4d	No	Maybe	Yes	Definetly
	2	6	9	12
4e	No	Maybe	Yes	Definetly
	3	7	8	11
5	Active	Passive		
	4	25	0	0

Table 4.8: Questionnaire (appendix II) results





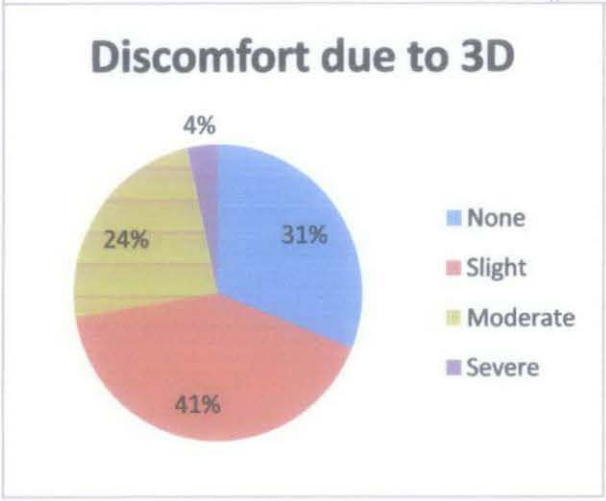


Figure 4.8: Questionnaire results

CHAPTER 5

Conclusion & Recommendations

The main objective of this project is to study how the brain responds to 3D and answer some questions associated with this kind of task that is done by the brain. How is it different from watching a normal 2D movie? What parts of the brain are activated during this task? The importance of this research comes from the fact that very little research has been done in this area.

The data gathering phase is over, as well as data cleaning, and data analysis using MATLAB and applying basic understanding of statistics using what has been learnt in the EEG training. All over we can conclude that concentration in 3D was less that in 2D as shown by the increased activity in Theta in case of 2D, the learning effect might have caused the activity in Beta to drop in case of 3D as the participants were watching the clips for the second time, that is why we suggest performing the same experiment but interchanging the sequence i.e. watching 3D before 2D. All these findings do not contradict with the fact that people seem to enjoy 3D more especially 3D Passive.

Some problems were faced during performing the experiments such as scheduling experiments with the participants; it is advised that this should be done at an earlier stage. We already attended a course about EEG signal analysis; however more reading and courses are required because this is a relatively new topic for those who don't come from biomedical engineering background and more knowledge is required about this branch of engineering.

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Appendix I

IMPORTANT NOTE: Filling this form does not mean that you are selected. You will be contacted in case you are shortlisted as a volunteer.

Participant Personal Information

Name:

Contact Number: **E-mail:**

Gender: ☐ Male ☐ Female **Race:**

Date of Birth: ___ (DD)/ ___ (MM)/ ___ (YY) **Age:**

Questionnaire

1. Have you ever experienced an EEG test before?

☐ Yes ☐ No

2. Are you taking any daily medications?

☐ Yes ☐ No

3. Do you have any current health problems of any sort (e.g.: diabetes, cancer, bed wetting, Etc.)?

☐ Yes ☐ No

4. How many hours do you usually sleep? Please tick ONE box only.

☐ less than 6 hours ☐ 6 to 8 hours ☐ more than 10 hours

5. Do you smoke?

☐ Yes ☐ No

6. How many hours per day (approximately) do you spend in front of a computer? Please tick ONE box only.

☐ less than 3 hours ☐ 3 to 6 hours ☐ 7 to 10 hours ☐ more than 10 hours

7. Do you wear glasses or contact lenses?

☐ If yes, please state your power: _____ ☐ No

8. Do you wear braces?

☐ YES ☐ NO

9. Have you ever experienced any form of severe head injury/ very high fever?

☐ ☐

YES NO

10. Do you have skin allergy? ☐ YES ☐ NO

10. How many have you watched times 3D movies before?

11. How many times per week do you see a movie?

11. Do you play video games? (Not at all, not active player, active player, very active player)

12. Have you played Nintendo DS before?

If yes, then please name the games that you have played.

13. Have you played Nintendo **3DS** before?

If yes, then please name the games that you have played.

14. Have you played Sony Playstation before?

If yes, then please name the games that you have played.

15. Have you played 3D game using Sony Playstation 3?

If yes, then please name the games that you have played.

16. Have you played any of the following games?

(i) Top gear

(ii) Football

(iii) War craft

IMPORTANT NOTE: Filling this form does not mean that you are selected. You will be contacted in case you are shortlisted as a volunteer.

Appendix II

Participant Personal Information

Name:

Contact Number: **E-mail:**

Gender: ☐ Male ☐ Female **Race:**

Date of Birth: ___ (DD)/ ___ (MM)/ ___ (YY) **Age:**

Answer by Y(yes) or N(no)

1- Did you feel energized because of 3D?

None Slight Moderate Severe

2- Do you have a general feeling of discomfort/ exhaustion because of 3D?

None Slight Moderate Severe

3- Did you feel better after watching the 3D movie?

None Slight Moderate Severe

4- Describe your experience with 3D movies by answering the following:

a. Do you like them better than 2D movies?

None Slight Moderate Severe

b. Will you want to watch 3D movies again?

No May be Yes Definitely

c. What were the best scenes that you saw?

Natural Buildings People

Other:

d. Would you encourage a learning technique that involves 3D?

No May be Yes Definitely

e. Will you prefer 3D movie over 2D movie?

No May be Yes Definitely

5- Do you prefer active glasses or passive glasses? Please explain your feelings.

ACTIVE PASSIVE

Appendix III

RESEARCH INFORMATION

Research Title: _____

Researcher's Name: _____

MMC Registration No. : _____

INTRODUCTION

You are invited to take part voluntarily in a research study of 3D vision: Games, Movies.

Your participation in this study is expected to last up to 3 hour. Up to 80 subjects will be participating in this study.

PURPOSE OF THE STUDY

The purpose of this study are to determine how does your brain perceive information presented in 3D compared to 2D.

QUALIFICATION TO PARTICIPATE

Requirments for participation in this study:

- Interested in watching 3D movies.
- Interested in playing video games.

You **cannot** participate in this study if:

- You have any medical history of head injury, epilepsy, or any other forms of psychotic disorders.
- You are under any type of daily medication.
- You have any type of skin allergy.

STUDY PROCEDURES

At your arrival to the experiment room, you will be given that Research information form. If you agree to participate. You will have to sign a consent form. Your head will be measured to select appropriate size of electrode cap. Two points will be marked on your forehead at 10% of the total distance from your anion to nasion. These marks are to locate the position of electrodes FP1 & FP2. The researcher in charge will explain to you about these terms.

The cap will be put on your head and two sponge donuts will be adhered on the marked points, so that the electrodes will be connected to your earlobes. To make good connectivity, your ears will be abraded with Nurep Paste and the electrodes will be filled with Nurep paste and the electrodes will be filled with electro gel. Electro Gel will also be injected in Electrocap electrodes for the same purpose with your scalp.

The impedance of all the electrodes will be measured and Electrocap electrodes may be abraded if they show high impedance. Two EEG sensors will be applied onto the second rib below the right and left shoulder blades. The application area will be cleaned and abraded to make good contact.
Two velcro straps will be sticked around your fore finger and middle finger to measure your skin conductance. The electrodes leads will be connected with these straps.
A photoplethysmogram (PPG) will be applied to your forefinger and will be fixed with a velcro strap.

The experiment includes the following:

1- 5 minutes eyes-closed test.
2- 5 minutes eyes-opened test.
3- 20 minutes 2D.
4- 5 minutes eyes-opened test.
5- 20 minutes 3D.
6- 5 minutes eyes-opened test.
7- 20 miutes 3D. (different type)

RISKS

There exists the possibility of risk and discomfort occurring during the test that could include skin irritation, allergy, or tears in eyes. To minimize these conditions, you will be frequently asked by the experimenter if you are experiencing any discomfort and your electroencephalogram will be closely monitored.

PARTICIPATION IN THE STUDY

Your taking part in this study is entirely voluntary. You may refuse to take part in the study or you may stop participation in the study at anytime, without a penalty or loss of benefits to which you are otherwise entitled. Your participation also may be stopped by the study doctor or sponsor without your consent.

QUESTIONS

If you have any question about this study or your rights, please contact:

<Name of Researcher> & <No. MMC>
<Department of>
<School>
<USM Health Campus>
<Contact No. Office > <Contact No. HP>

If you have any questions regarding the Ethical Approval or any issue / problem related to this study, please contact:

Puan Mazlita Zainal Abidin
Secretary of Research Ethics Committee (Human) USM
Clinical Sciences Research Platform
USM Health Campus
Tel. No. : 09-767 2355 / 09-767 2352

Email : jepem@kk.usm.my

CONFIDENTIALITY

Your information will be kept confidential by the study staff and will not be made publicly available unless disclosure is required by law.

Data obtained from this study that does not identify you individually will be published for knowledge purposes.

Your medical information may be held and processed on a computer.

By signing this consent form, you authorize the record review, information storage and data transfer described above.

SIGNATURES

To be entered into the study, you or a legal representative must sign and date the signature page **[ATTACHMENT S or ATTACHMENT G (for genetic sample only) or ATTACHMENT P]**

Subject Information and Consent Form
(Signature Page)

Research Title: _____

Researcher's Name: _____

To become a part this study, you or your legal representative must sign this page. By signing this page, I am confirming the following:

- I have read all of the information in this Subject Information and Consent Form **including any information regarding the risk in this study** and I have had time to think about it.
- All of my questions have been answered to my satisfaction.
- I voluntarily agree to be part of this research study, to follow the study procedures, and to provide necessary information to the doctor, nurses, or other staff members, as requested.
- I may freely choose to stop being a part of this study at anytime.
- I have received a copy of this Subject Information and Consent Form to keep for myself.

_____ _____

Subject Name : Print or type) **Subject Initials** and **Number**

_____ _____

Subject I.C No. (New) **Subject** I.C No. (Old)

_____ _____

Signature of Subject or Legal Representative **Date** (dd/MM/yy)
(Add time if applicable)

_____

Name of Individual
Conducting Consent Discussion (Print or Type)

_____ _____

Signature of Individual **Date** (dd/MM/yy)
Conducting Consent Discussion

_____ _____

Name & Signature of Witness **Date** (dd/MM/yy)

Note : All subject subjects who are involved in this study will not be covered by insurance

Subject/ Subject Information and Consent Form (Signature Page)

Research Title: _____

Researcher's Name: _____

To become a part this study, you or your legal representative must sign this page. By signing this page, I am confirming the following:

- I have read all of the information in this Subject Information and Consent Form **including any information regarding the risk in this study** and I have had time to think about it.
- All of my questions have been answered to my satisfaction.
- I voluntarily agree to be part of this research study, to follow the study procedures, and to provide necessary information to the doctor, nurses, or other staff members, as requested.
- I may freely choose to stop being a part of this study at anytime.
- I have received a copy of this Subject Information and Consent Form to keep for myself.

Subject Name (Print or type)	**Subject Initials and Number**
Subject I.C No. (New)	**Subject I.C No. (Old)**
Signature of subject or Legal Representative	**Date** (dd/MM/yy) (Add time if applicable)
Name of Individual conducting Consent Discussion (Print or Type)	
Signature of Individual Conducting Consent Discussion	**Date** (dd/MM/yy)
Name & Signature of Witness	**Date** (dd/MM/yy)

Note : All subjects/subjects who are involved in this study will not be covered by insurance

: Excess samples from this research will not be used for other reasons and will be destroyed with the consent from the Research Ethics Committee (Human), USM.

Subject's Material Publication Consent Form
Signature Page

Research Title: _____

Researcher's Name: _____

To become a part this study, you or your legal representative must sign this page.

By signing this page, I am confirming the following:

- I understood that my name will not appear on the materials published and there has been efforts to make sure that the privacy of my name is kept confidential although the confidentiality is not completely guaranteed due to unexpected circumstances.
- I have read the materials or general description of what the material contains and reviewed all photographs and figures in which I am included that could be published.
- I have been offered the opportunity to read the manuscript and to see all materials in which I am included, but have waived my right to do so.
- All the published materials will be shared among the medical practitioners, scientists and journalist world wide.
- The materials will also be used in local publications, book publications and accessed by many local and international doctors world wide.
- I hereby agree and allow the materials to be used in other publications required by other publishers with these conditions:
- The materials will not be used as advertisement purposes nor as packaging materials.
- The materials will not be used out of contex – i.e.: Sample pictures will not be used in an article which is unrelated subject to the picture.

_____ _____

Subject Name (Print or type) **Subject Initials or Number**

_____ _____ _____

Subject I.C No. Subject's Signature **Date** (ddMMMyy)

_____ _____

Name and Signature of Individual Conducting Consent Discussion **Date** (ddMMMyy)

Note : All subjects/objects who are involved in this study will not be covered by insurance

Appendix IV

```
clear all
close all
clc
%% Read xls files
% Declare empty matrices
AbsPowerMat = [];
CoherenceMat = [];
PhaseLagMat = [];
Path = 'Yin';
NumSessions = 6;
% Read the data for all sessions of the 2D part
%% 2D part
for i = 1:NumSessions
    [AbsPowerMat(:,:,i), ~, ~] = xlsread([Path,'\2D\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'B60:K78');
    [CoherenceMat(:,:,i), ~, ~] = xlsread([Path,'\2D\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'C366:L536');
    [PhaseLagMat(:,:,i), ~, ~] = xlsread([Path,'\2D\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'C544:L714');
end
% Average the data across sessions of the 2D part

AbsPowr2D = mean(AbsPowerMat, 3);
Coherence2D = mean(CoherenceMat, 3);
PhaseLag2D = mean(PhaseLagMat, 3);
%% 3D Active part
for i = 1:NumSessions
    [AbsPowerMat(:,:,i), ~, ~] = xlsread([Path,'\3D Active\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'B60:K78');
    [CoherenceMat(:,:,i), ~, ~] = xlsread([Path,'\3D Active\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'C366:L536');
    [PhaseLagMat(:,:,i), ~, ~] = xlsread([Path,'\3D Active\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'C544:L714');
end
% Average the data across sessions of the 3D active part

AbsPowr3DActive = mean(AbsPowerMat, 3);
Coherence3DActive = mean(CoherenceMat, 3);
PhaseLag3DActive = mean(PhaseLagMat, 3);
```

```
%% 3D Passive part
for i = 1:NumSessions
    [AbsPowerMat(:,:,i), ~, ~] = xlsread([Path,'\3D Passive\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'B60:K78');
    [CoherenceMat(:,:,i), ~, ~] = xlsread([Path,'\3D Passive\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'C366:L536');
    [PhaseLagMat(:,:,i), ~, ~] = xlsread([Path,'\3D Passive\session ', ...
        sprintf('%d',i), '.xlsx'], 1, 'C544:L714');
end
% Average the data across sessions of the 3D passive part
AbsPowr3DPassive = mean(AbsPowerMat, 3);
% save data as mat file
% save('AbsPowr3DPassive', AbsPowr3DPassive);
Coherence3DPassive = mean(CoherenceMat, 3);
PhaseLag3DPassive = mean(PhaseLagMat, 3);

%% Data Analysis
% Process absolute power of 2D and 3D Active
CondOneAPAc=0;
CondTwoAPAc=0;
CondThreeAPAc=0;
CondFourAPAc=0;
CondFiveAPAc=0;
CondSixAPAc=0;


 AbsDiff3DActive=[];
    for i = 1:19
       for j = 1:10
        if   (AbsPowr2D(i,j)   >   0)&&(AbsPowr3DActive(i,j)   >   0)   &&
(AbsPowr3DActive(i,j)> AbsPowr2D(i,j))
        AbsDiff3DActive(i,j)=  AbsPowr3DActive(i,j) - AbsPowr2D(i,j);
    CondOneAPAc=CondOneAPAc+1;

        else

        if   (AbsPowr2D(i,j)   >   0)&&(AbsPowr3DActive(i,j)   >   0)   &&
(AbsPowr3DActive(i,j)< AbsPowr2D(i,j))

           AbsDiff3DActive(i,j)=  AbsPowr3DActive(i,j) - AbsPowr2D(i,j);
```

```
            CondTwoAPAc=CondTwoAPAc+1;

        else
            if  (AbsPowr2D(i,j) < 0)&&(AbsPowr3DActive(i,j) > 0)

               AbsDiff3DActive(i,j)=          AbsPowr3DActive(i,j)      -
AbsPowr2D(i,j);
                   CondThreeAPAc=CondThreeAPAc+1;



            else
                if (AbsPowr2D(i,j)> 0)&&(AbsPowr3DActive(i,j) < 0)
              AbsDiff3DActive(i,j)=  AbsPowr3DActive(i,j) - AbsPowr2D(i,j);

                CondFourAPAc=CondFourAPAc+1;

            else
                if(AbsPowr2D(i,j)  <  0)&&(AbsPowr3DActive(i,j)  <  0)  &&
(AbsPowr3DActive(i,j)> AbsPowr2D(i,j))
           AbsDiff3DActive(i,j)=  AbsPowr3DActive(i,j) - AbsPowr2D(i,j);
                CondFiveAPAc=CondFiveAPAc+1;



                else
                     if(AbsPowr2D(i,j) < 0)&&(AbsPowr3DActive(i,j) < 0) &&
(AbsPowr3DActive(i,j)< AbsPowr2D(i,j))
                AbsDiff3DActive(i,j)=          AbsPowr3DActive(i,j)      -
AbsPowr2D(i,j);
                           CondSixAPAc=CondSixAPAc+1;

                     end
                end
                end
            end
        end
        end
       end
```

```
    end
     save([Path, '\AbsDiff3DActive.mat'], 'AbsDiff3DActive');

TotalCondAPAc=CondOneAPAc+CondTwoAPAc+CondThreeAPAc+CondFourAPAc+CondFiveAP
Ac+CondSixAPAc;
  Plot3DbarChart(AbsDiff3DActive, 1);
  FiguresCounter = 1;

  %% Data Analysis2
% Process absolute power of 2D and 3D Passive

CondOneAPPa=0;
CondTwoAPPa=0;
CondThreeAPPa=0;
CondFourAPPa=0;
CondFiveAPPa=0;
CondSixAPPa=0;

 AbsDiff3DPassive=[];
    for i = 1:19
       for j = 1:10
        if   (AbsPowr2D(i,j)   >   0)&&(AbsPowr3DPassive(i,j)   >   0)   &&
(AbsPowr3DPassive(i,j)> AbsPowr2D(i,j))
        AbsDiff3DPassive(i,j)=  AbsPowr3DPassive(i,j) - AbsPowr2D(i,j);

   CondOneAPPa=CondOneAPPa+1;

        else

        if   (AbsPowr2D(i,j)   >   0)&&(AbsPowr3DPassive(i,j)   >   0)   &&
(AbsPowr3DPassive(i,j)< AbsPowr2D(i,j))

          AbsDiff3DPassive(i,j)=  AbsPowr3DPassive(i,j) - AbsPowr2D(i,j);
         CondTwoAPPa=CondTwoAPPa+1;

        else
            if  (AbsPowr2D(i,j) < 0)&&(AbsPowr3DPassive(i,j) > 0)
```

```
                AbsDiff3DPassive(i,j)=          AbsPowr3DPassive(i,j)      -
AbsPowr2D(i,j);
                CondThreeAPPa=CondThreeAPPa+1;


              else
                  if (AbsPowr2D(i,j)> 0)&&(AbsPowr3DPassive(i,j) < 0)
                AbsDiff3DPassive(i,j)=          AbsPowr3DPassive(i,j)      -
AbsPowr2D(i,j);

              CondFourAPPa=CondFourAPPa+1;
              else
                  if(AbsPowr2D(i,j)  <  0)&&(AbsPowr3DPassive(i,j)  <  0)  &&
(AbsPowr3DPassive(i,j)> AbsPowr2D(i,j))
             AbsDiff3DPassive(i,j)=  AbsPowr3DPassive(i,j) - AbsPowr2D(i,j);
             CondFiveAPPa=CondFiveAPPa+1;



                  else
                       if(AbsPowr2D(i,j) < 0)&&(AbsPowr3DPassive(i,j) < 0) &&
(AbsPowr3DPassive(i,j)< AbsPowr2D(i,j))
                  AbsDiff3DPassive(i,j)=          AbsPowr3DPassive(i,j)      -
AbsPowr2D(i,j);

           CondSixAPPa=CondSixAPPa+1;
                       end
                  end
                  end
              end
          end
          end
         end


     end
          save([Path, '\AbsDiff3DPassive.mat'], 'AbsDiff3DPassive');


TotalCondAPPa=CondOneAPPa+CondTwoAPPa+CondThreeAPPa+CondFourAPPa+CondFiveAP
Pa+CondSixAPPa;
```

```
    Plot3DbarChart(AbsDiff3DPassive, 2);
    FiguresCounter = FiguresCounter + 1;

   %% Data Analysis Coherence
% Process Coherence of 2D and 3D Active

CondOneCohAc=0;
CondTwoCohAc=0;
CondThreeCohAc=0;
CondFourCohAc=0;

CohDiff3DActive=[];

    for i = 1:171
       for j = 1:10
        if (Coherence2D(i,j) > 0.3)&&(Coherence3DActive(i,j) > 0.3)

            CohDiff3DActive(i,j)=          Coherence3DActive(i,j)      -
Coherence2D(i,j);

             CondOneCohAc=CondOneCohAc+1;

        else
            if  (Coherence2D(i,j) < 0)&&(Coherence3DActive(i,j) > 0.3)

               CohDiff3DActive(i,j)=  Coherence3DActive(i,j);
                        CondTwoCohAc=CondTwoCohAc+1;



            else
                if (Coherence2D(i,j)> 0.3)&&(Coherence3DActive(i,j) < 0)

              CohDiff3DActive(i,j)=  -Coherence2D(i,j);
                              CondThreeCohAc=CondThreeCohAc + 1;



            else
                if(Coherence2D(i,j) < 0)&&(Coherence3DActive(i,j) < 0)
```

```
                    CohDiff3DActive(i,j)=  0;
                        CondFourCohAc=CondFourCohAc + 1;



                end
                end
            end
        end
       end
    end
        save([Path, '\CohDiff3DActive.mat'], 'CohDiff3DActive');
TotalCondCohAc = CondOneCohAc+CondTwoCohAc+CondThreeCohAc+CondFourCohAc;
    % Convert coherence from 1D to 2D
    CohDiff3DActive1 = [];
    for i = 1:10
        CohDiff3DActive1(:,:,i) = ConnectTrans1Dto2D(CohDiff3DActive(:,i));
        % plot 3D bar chart for cohernece
       Plot3DChartConnectivity(CohDiff3DActive1(:,:,i), FiguresCounter, i);

        % Plot connectivity map for coherence
        PlotConnectivity(CohDiff3DActive1(:,:,i), FiguresCounter, i);
    end
 FiguresCounter = FiguresCounter + 32;



% 5) b) Data Analysis3 Consernce
% Process Coherence of 2D and 3D passive

CondOneCohPa=0;
CondTwoCohPa=0;
CondThreeCohPa=0;
CondFourCohPa=0;

CohDiff3DPassive=[];
    for i = 1:171
       for j = 1:10
        if (Coherence2D(i,j) > 0.3)&&(Coherence3DPassive(i,j) > 0.3)
```

```
            CohDiff3DPassive(i,j)=            Coherence3DPassive(i,j)      -
Coherence2D(i,j);
            CondOneCohPa= CondOneCohPa +1;



        else
            if  (Coherence2D(i,j) < 0)&&(Coherence3DPassive(i,j) > 0.3)

               CohDiff3DPassive(i,j)=  Coherence3DPassive(i,j);
                        CondTwoCohPa= CondTwoCohPa +1;



            else
                if (Coherence2D(i,j)> 0.3)&&(Coherence3DPassive(i,j) < 0)

              CohDiff3DPassive(i,j)= - Coherence2D(i,j);
                             CondThreeCohPa= CondThreeCohPa +1;



            else
                if(Coherence2D(i,j) < 0)&&(Coherence3DPassive(i,j) < 0)

                    CohDiff3DPassive(i,j)=  0;
                       CondFourCohPa= CondFourCohPa +1;




                end
                end
            end
         end
        end
    end
    save([Path, '\CohDiff3DPassive.mat'], 'CohDiff3DPassive');
    TotalCondCohPa                                                    =
CondOneCohPa+CondTwoCohPa+CondThreeCohPa+CondFourCohPa;
```

```
    CohDiff3DPassive1 = [];
   for i = 1:10
        CohDiff3DPassive1(:,:,i)                                    =
ConnectTrans1Dto2D(CohDiff3DPassive(:,i));
        % plot 3D bar chart for cohernece
       Plot3DChartConnectivity(CohDiff3DPassive1(:,:,i),    FiguresCounter,
i);

        % Plot connectivity map for coherence
        PlotConnectivity(CohDiff3DPassive1(:,:,i), FiguresCounter, i);
    end

     FiguresCounter = FiguresCounter + 32;

    %}
    % Data Analysis3 PhaseLag
% Process Phase lag of 2D and 3D Active
CondOnePLAc=0;
CondTwoPLAc=0;
CondThreePLAc=0;
CondFourPLAc=0;
CondFivePLAc=0;

PhaseDiff3DActive=[];
    for i = 1:171
       for j = 1:10
        if (PhaseLag2D(i,j) > 0.7)&&(PhaseLag3DActive(i,j) > 0.7)

            PhaseDiff3DActive(i,j)=          PhaseLag3DActive(i,j)      -
PhaseLag2D(i,j);
               CondOnePLAc=CondOnePLAc+1;



        else
            if  (PhaseLag2D(i,j) < -0.7)&&(PhaseLag3DActive(i,j) > -0.7)

               PhaseDiff3DActive(i,j)=  PhaseLag2D(i,j);
                  CondTwoPLAc=CondTwoPLAc+1;
```

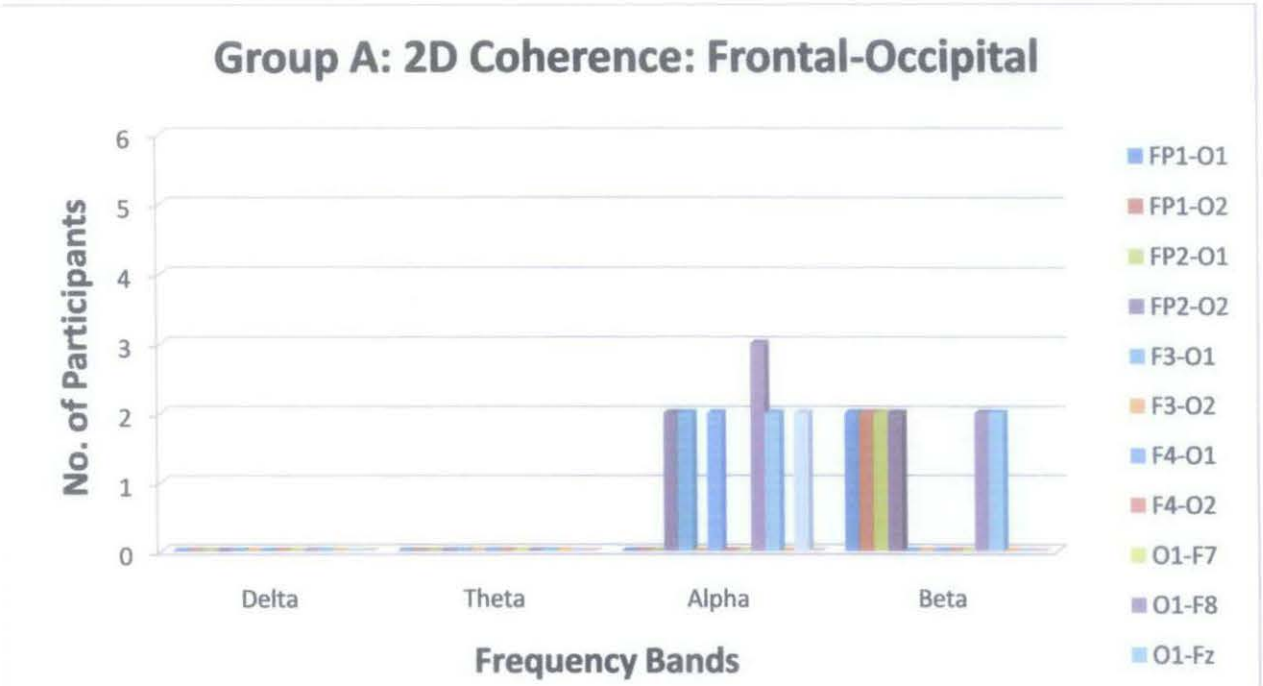
```
            else
                if (PhaseLag2D(i,j)> -0.7)&&(PhaseLag3DActive(i,j) < -0.7)

              PhaseDiff3DActive(i,j)= - PhaseLag3DActive(i,j);
                    CondThreePLAc=CondThreePLAc+1;



            else
                if(PhaseLag2D(i,j) < -0.7)&&(PhaseLag3DActive(i,j) < -0.7)

                    PhaseDiff3DActive(i,j)=     PhaseLag3DActive(i,j)     -
PhaseLag2D(i,j);

                CondFourPLAc=CondFourPLAc+1;

                else

            PhaseDiff3DActive(i,j)=0;
            CondFivePLAc=CondFivePLAc+1;




                end
                end
            end
         end
        end
    end
    save([Path, '\PhaseDiff3DActive.mat'], 'PhaseDiff3DActive');
    TotalCondPLAc                                                    =
CondOnePLAc+CondTwoPLAc+CondThreePLAc+CondFourPLAc+CondFivePLAc;

    PhaseDiff3DActive2 = [];

   for i = 1:10
         PhaseDiff3DActive2(:,:,i)                                   =
ConnectTrans1Dto2D(PhaseDiff3DActive(:,i));
        % plot 3D bar chart for coherence
       Plot3DChartPhaselag( PhaseDiff3DActive2(:,:,i), FiguresCounter, i);
```

```
        % Plot connectivity map for coherence
        PlotConnectivity( PhaseDiff3DActive2(:,:,i), FiguresCounter, i);
    end

     FiguresCounter = FiguresCounter + 32;


     % Data Analysis3 PhaseLag
% Process Phase lag of 2D and 3D Passive

CondOnePLPa=0;
CondTwoPLPa=0;
CondThreePLPa=0;
CondFourPLPa=0;
CondFivePLPa=0;

PhaseDiff3DPassive=[];
    for i = 1:171
       for j = 1:10
        if (PhaseLag2D(i,j) > 0.7)&&(PhaseLag3DPassive(i,j) > 0.7)

            PhaseDiff3DPassive(i,j)=          PhaseLag3DPassive(i,j)      -
PhaseLag2D(i,j);
       CondOnePLPa= CondOnePLPa +1;



        else
            if  (PhaseLag2D(i,j) < -0.7)&&(PhaseLag3DPassive(i,j) > -0.7)

               PhaseDiff3DPassive(i,j)=  PhaseLag2D(i,j);
                 CondTwoPLPa= CondTwoPLPa +1;



            else
                if (PhaseLag2D(i,j)> -0.7)&&(PhaseLag3DPassive(i,j) < -0.7)

              PhaseDiff3DPassive(i,j)=  -PhaseLag3DPassive(i,j);
```

```
                    CondThreePLPa= CondThreePLPa +1;


            else
                if(PhaseLag2D(i,j) < -0.7)&&(PhaseLag3DPassive(i,j) < -0.7)

                    PhaseDiff3DPassive(i,j)=    PhaseLag3DPassive(i,j)    -
PhaseLag2D(i,j);
                        CondFourPLPa= CondFourPLPa +1;

            else

             PhaseDiff3DPassive(i,j)=0;
              CondFivePLPa=CondFivePLPa+1;

                end
                end
             end
          end
         end
     end
     save([Path,'\PhaseDiff3DPassive.mat'],'PhaseDiff3DPassive');
      PhaseDiff3DPassive2 = [];
     TotalCondPLPa                                                    =
CondOnePLPa+CondTwoPLPa+CondThreePLPa+CondFourPLPa+CondFivePLPa;

    for i = 1:10
          PhaseDiff3DPassive2(:,:,i)                                  =
ConnectTrans1Dto2D(PhaseDiff3DPassive(:,i));
         % plot 3D bar chart for cohernece
        Plot3DChartPhaselag( PhaseDiff3DPassive2(:,:,i), FiguresCounter, i);

         % Plot connectivity map for coherence
         PlotConnectivity( PhaseDiff3DPassive2(:,:,i), FiguresCounter, i);
     end

      FiguresCounter = FiguresCounter + 32;
%% Saving figures Active Coherence
```

```
FreqBand = {'Delta',    'Theta',    'Alpha',    'Beta', 'High Beta', 'Alpha
1', 'Alpha 2',  ...
    'Beta 1',   'Beta 2',   'Beta 3'};
hgsave(figure(1),[Path,'\AbsPowerDiff3DAcitve.fig']);
hgsave(figure(2),[Path,'\AbsPowerDiff3DPassive.fig']);
for i=1:10
    % Coherence active
    hgsave(figure(2+i),[Path,'\Cohernece       Active       map-barchart-',
FreqBand{i},'.fig']);
    hgsave(figure(12+i),[Path,'\Cohernece      Active      bar      chart-',
FreqBand{i},'.fig']);
    hgsave(figure(22+i),[Path,'\Cohernece           Active           map-',
FreqBand{i},'.fig']);

end
hgsave(figure(33),[Path,'\Cohernece Active bar chart.fig']);
hgsave(figure(34),[Path,'\Cohernece Active map.fig']);



%% Saving figures Passive Coherence
  % Coherence Passive
  for i=1:10
    hgsave(figure(34+i),[Path,'\Cohernece      Passive      map-barchart-',
FreqBand{i},'.fig']);
    hgsave(figure(44+i),[Path,'\Cohernece      Passive      bar      chart-',
FreqBand{i},'.fig']);
    hgsave(figure(54+i),[Path,'\Cohernece           Passive           map-',
FreqBand{i},'.fig']);

end
hgsave(figure(65),[Path,'\Cohernece Passive bar chart.fig']);
hgsave(figure(66),[Path,'\Cohernece Passive map.fig']);

%% Saving figures Active phaselag
  % Active phaselag
  for i=1:10
    hgsave(figure(66+i),[Path,'\PhaseLag       Active       map-barchart-',
FreqBand{i},'.fig']);
    hgsave(figure(76+i),[Path,'\PhaseLag      Active      bar      chart-',
FreqBand{i},'.fig']);
```

```
    hgsave(figure(86+i),[Path,'\PhaseLag            Active            map-',
FreqBand{i},'.fig']);

end
hgsave(figure(97),[Path,'\PhaseLag Active bar chart.fig']);
hgsave(figure(98),[Path,'\PhaseLag Active map.fig']);
%%
%Saving figures Passive phaselag
  % Active phaselag
  for i=1:10
    hgsave(figure(98+i),[Path,'\PhaseLag       Passive       map-barchart-',
FreqBand{i},'.fig']);
    hgsave(figure(108+i),[Path,'\PhaseLag      Passive      bar      chart-',
FreqBand{i},'.fig']);
    hgsave(figure(118+i),[Path,'\PhaseLag           Passive           map-',
FreqBand{i},'.fig']);
end
hgsave(figure(129),[Path, '\PhaseLag Passive bar chart.fig']);
hgsave(figure(130),[Path,'\PhaseLag Passive map.fig']);
```



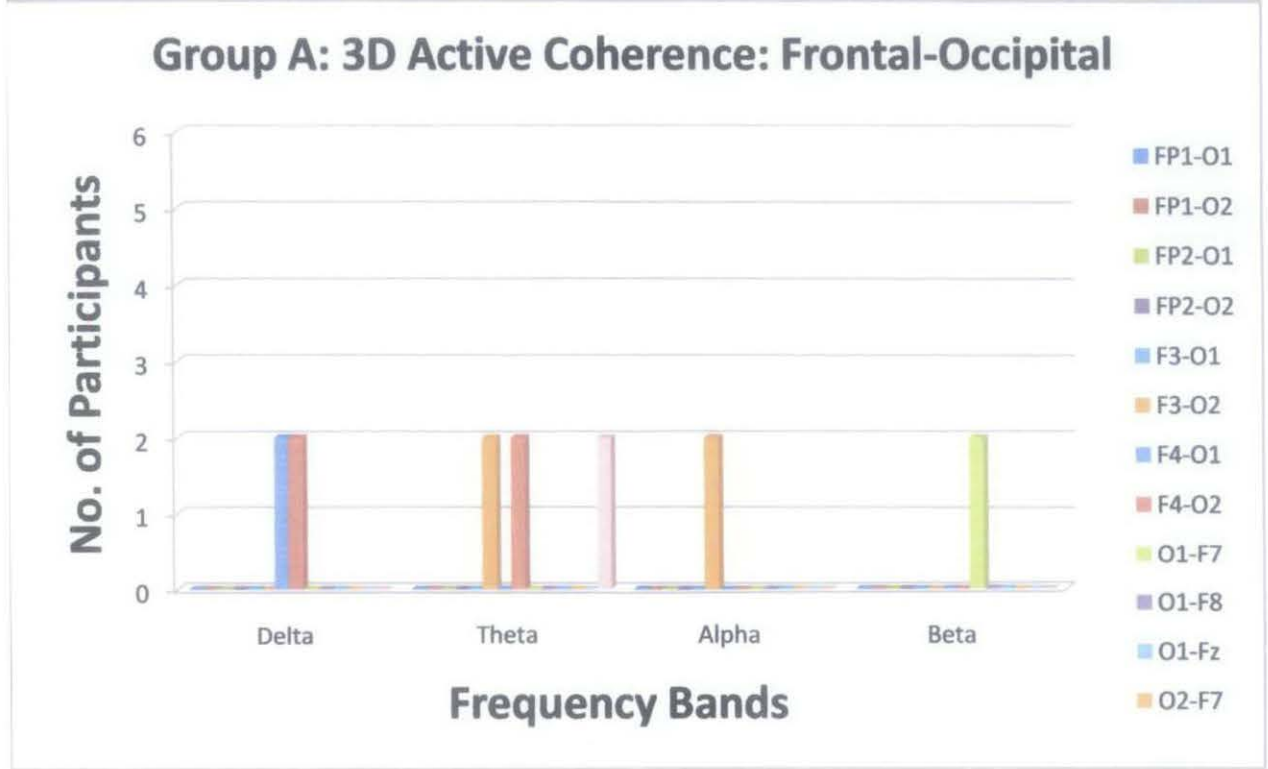


Figure 1: Group A Coherence: Frontal- Occipital

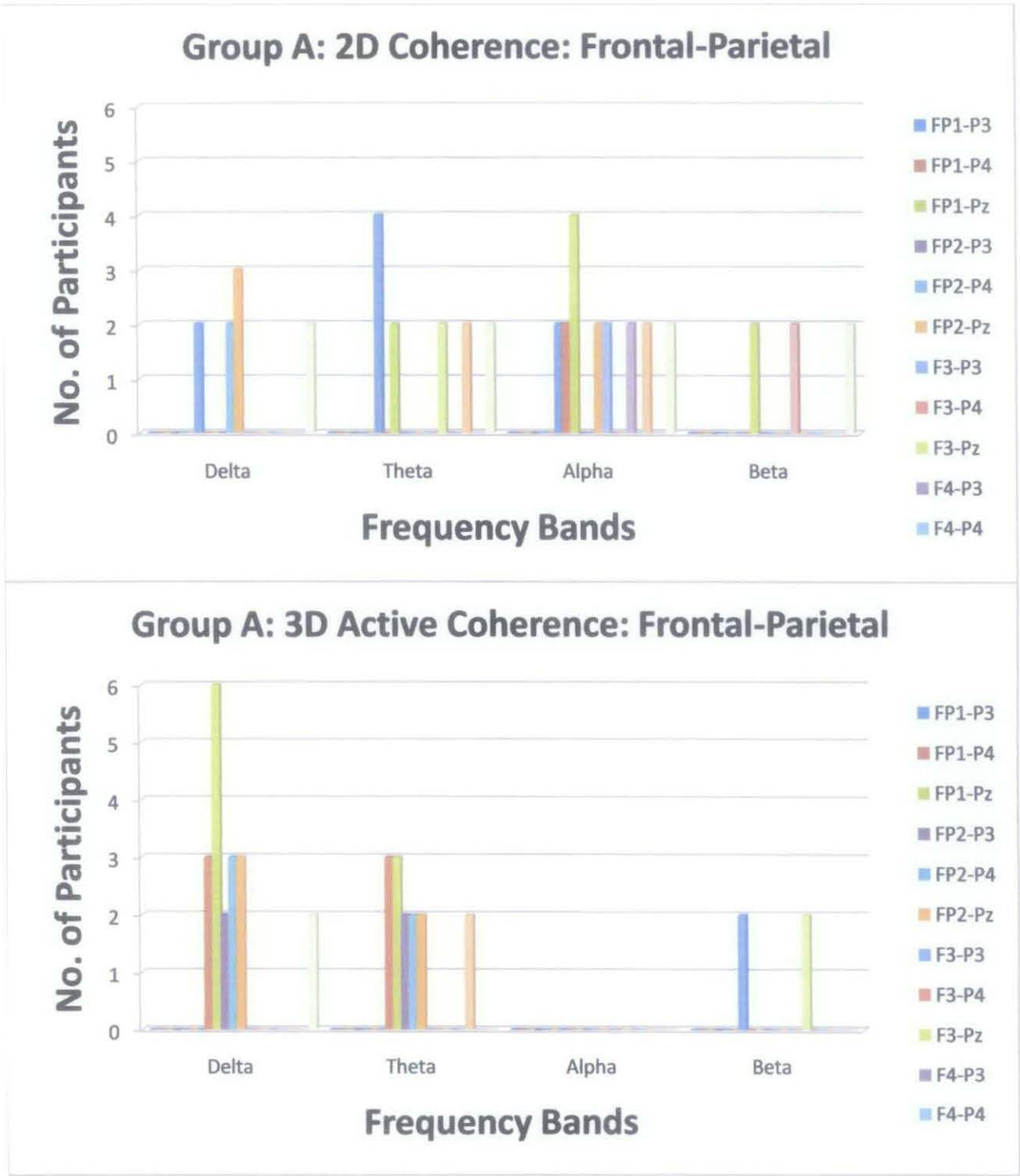


Figure 2: Group A Coherence: Frontal- Parietal

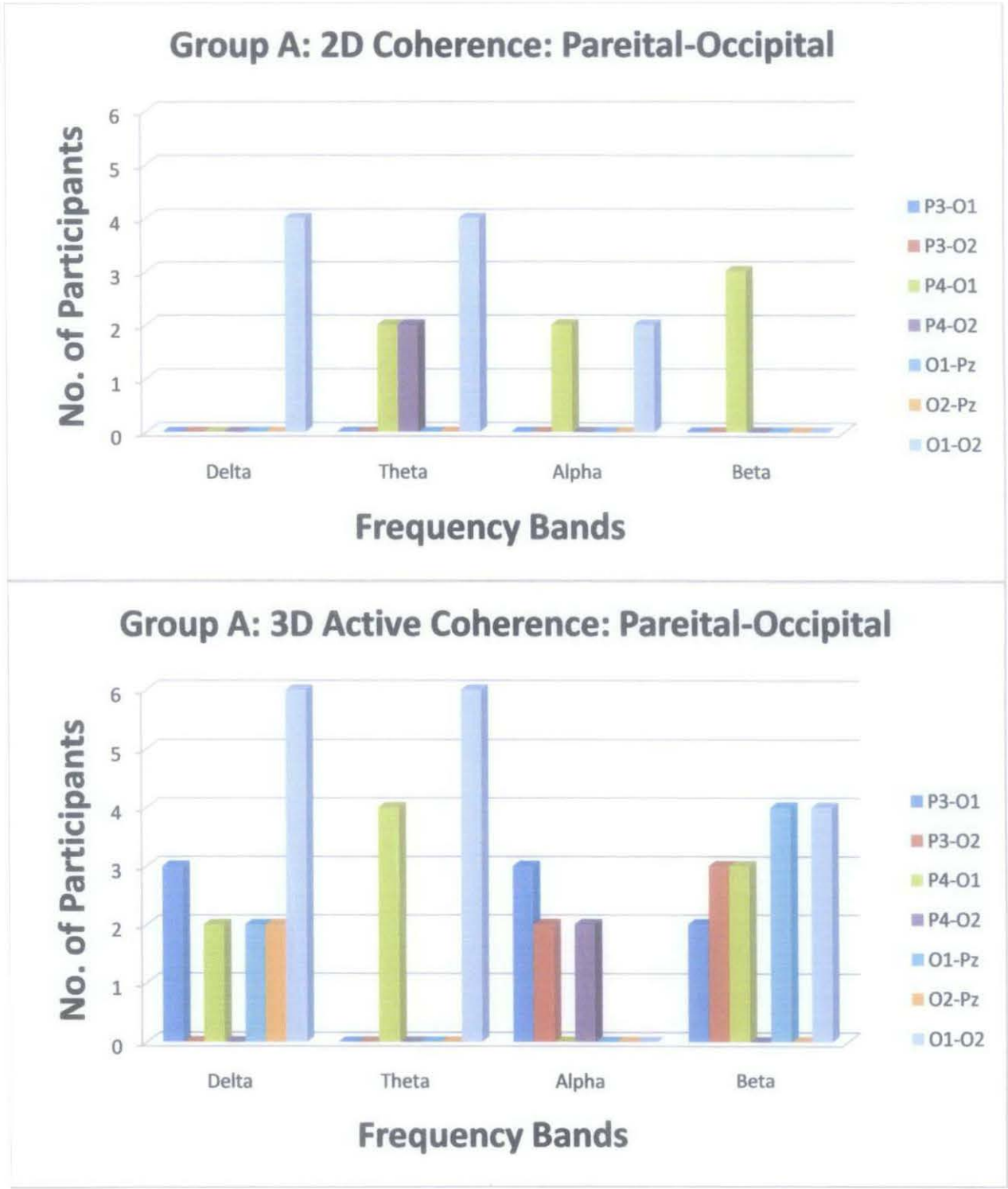


Figure 3: Group A Coherence: Parietal - Occipital

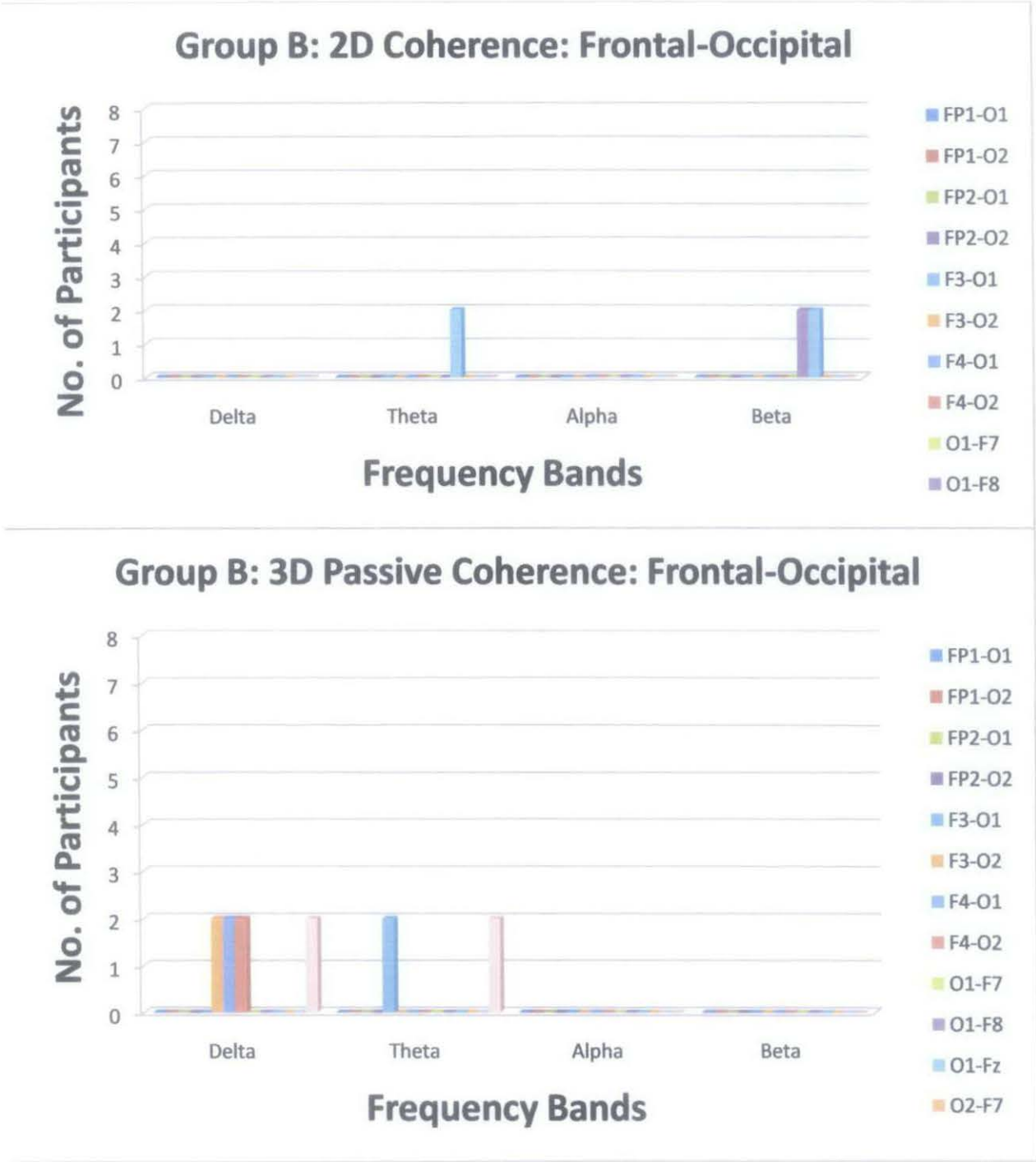


Figure 4: Group B Coherence: Frontal - Occipital

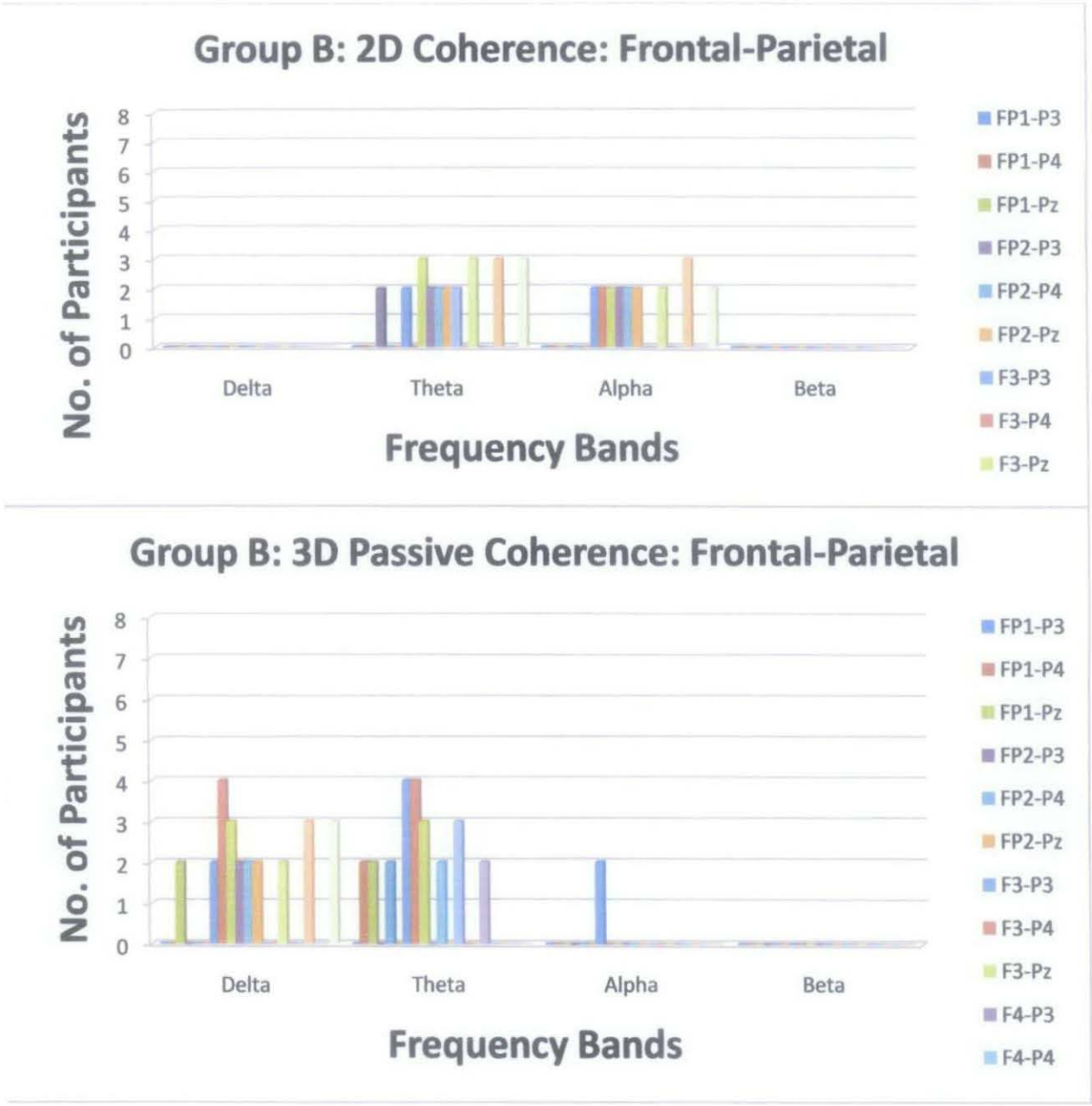


Figure 5: Group B Coherence: Frontal - Parietal

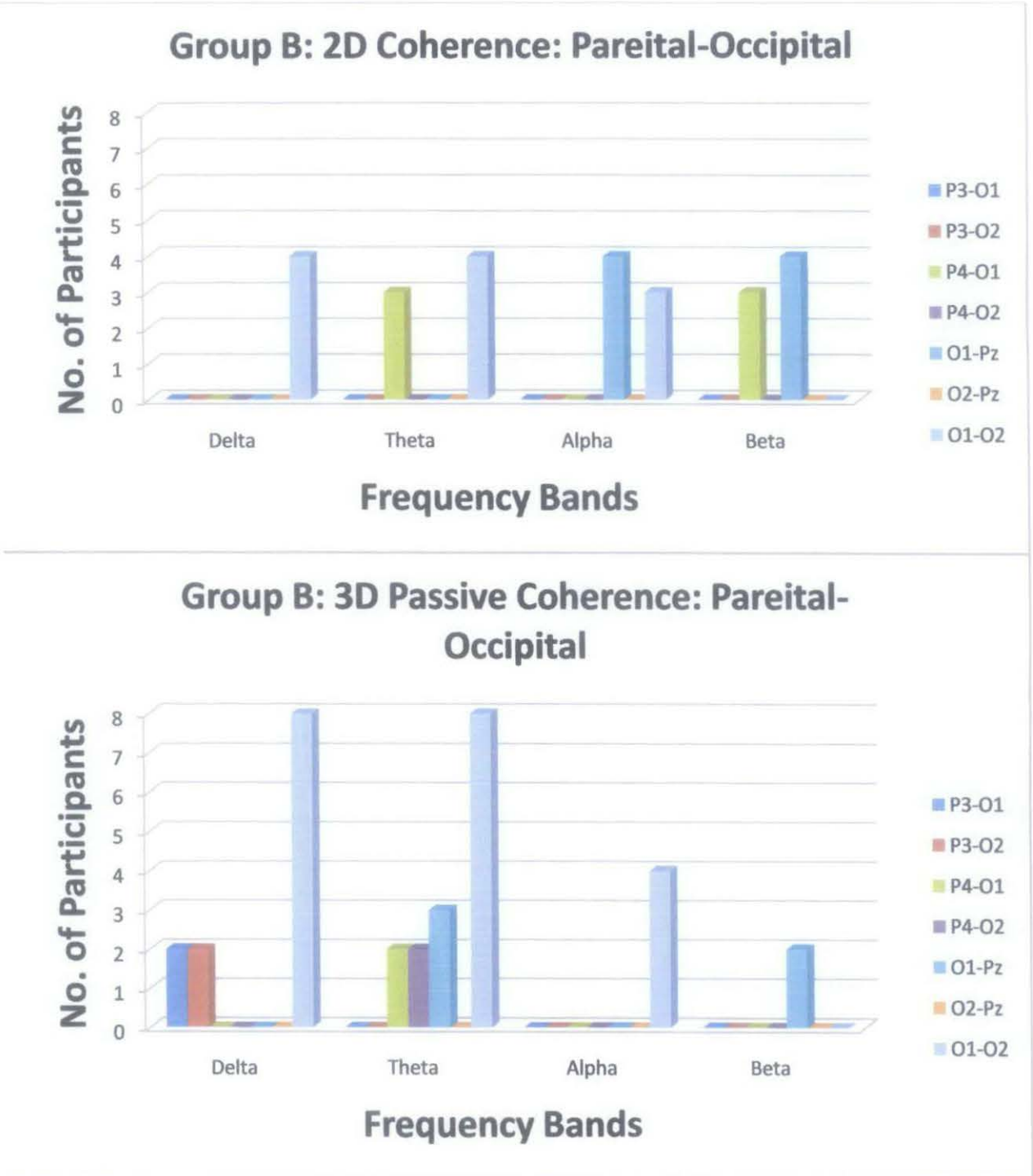


Figure 6: Group B Coherence: Parietal - Occipital

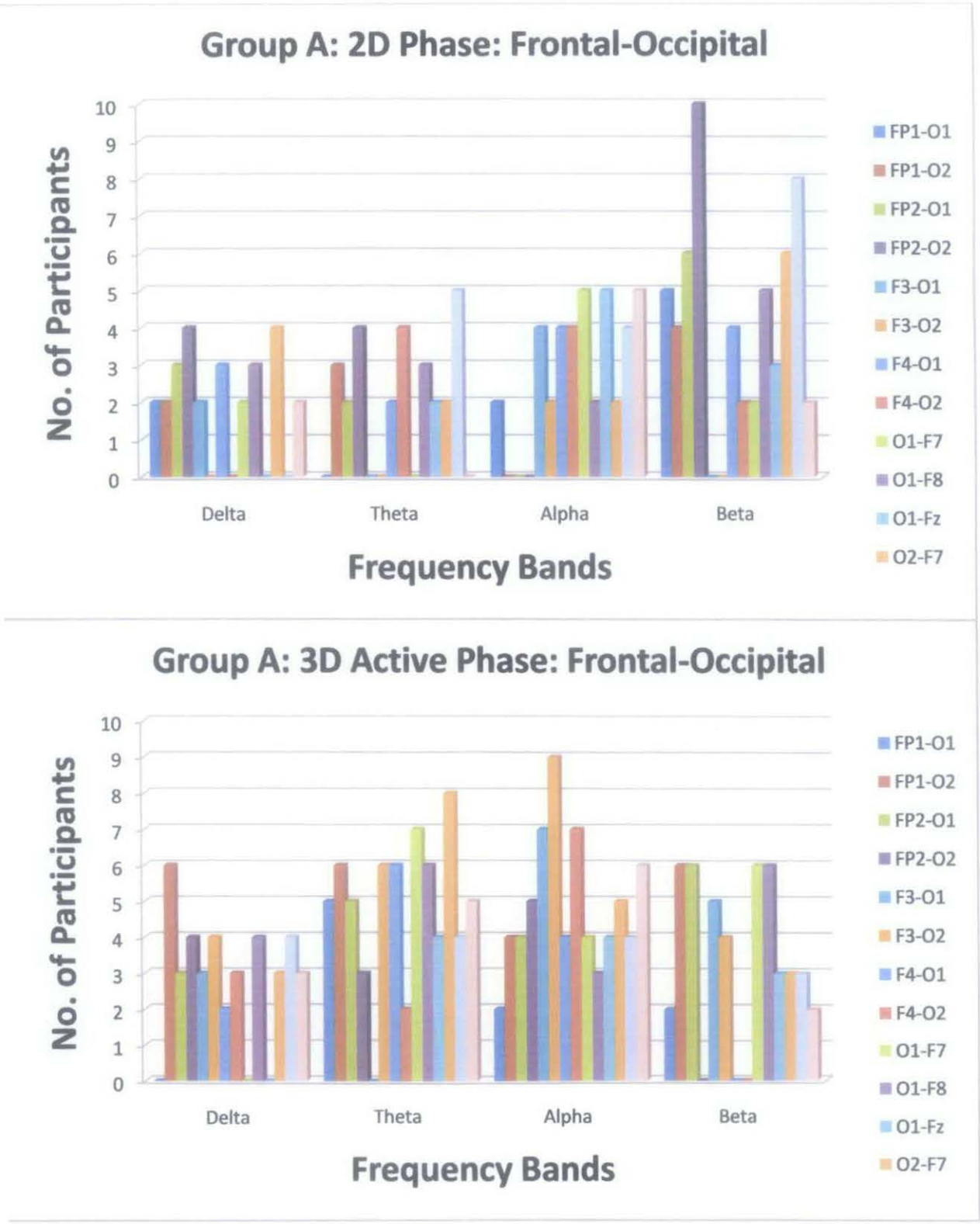
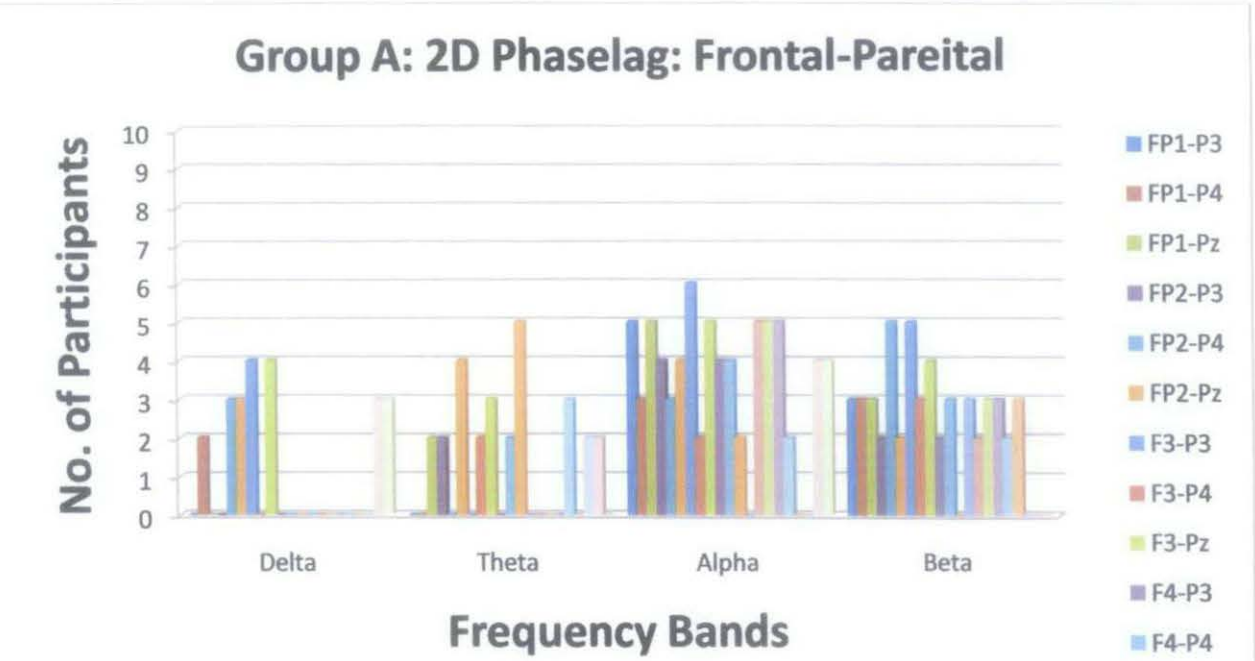


Figure 7: Group A Phase: Frontal - Occipital



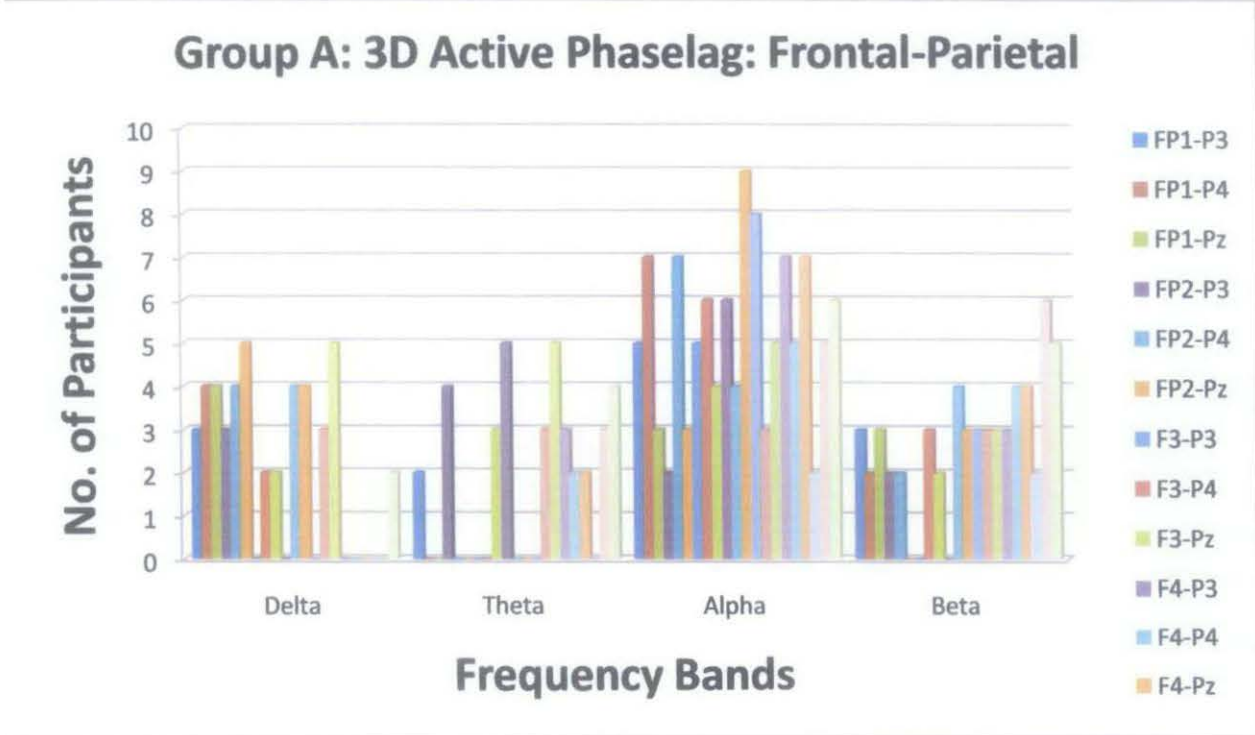


Figure 8: Group A Phase: Frontal - Parietal

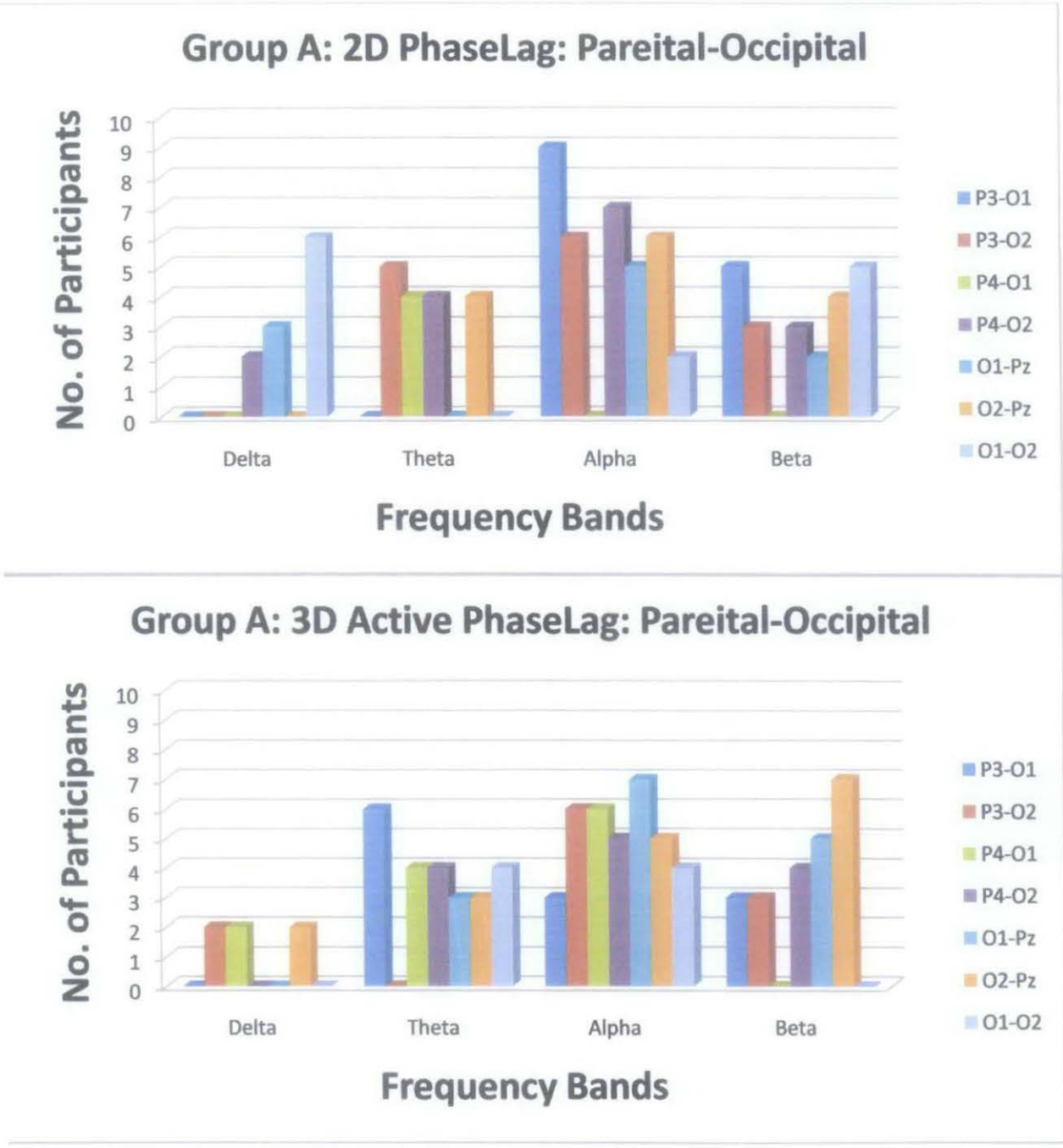


Figure 9: Group A Phase: Parietal - Occipital

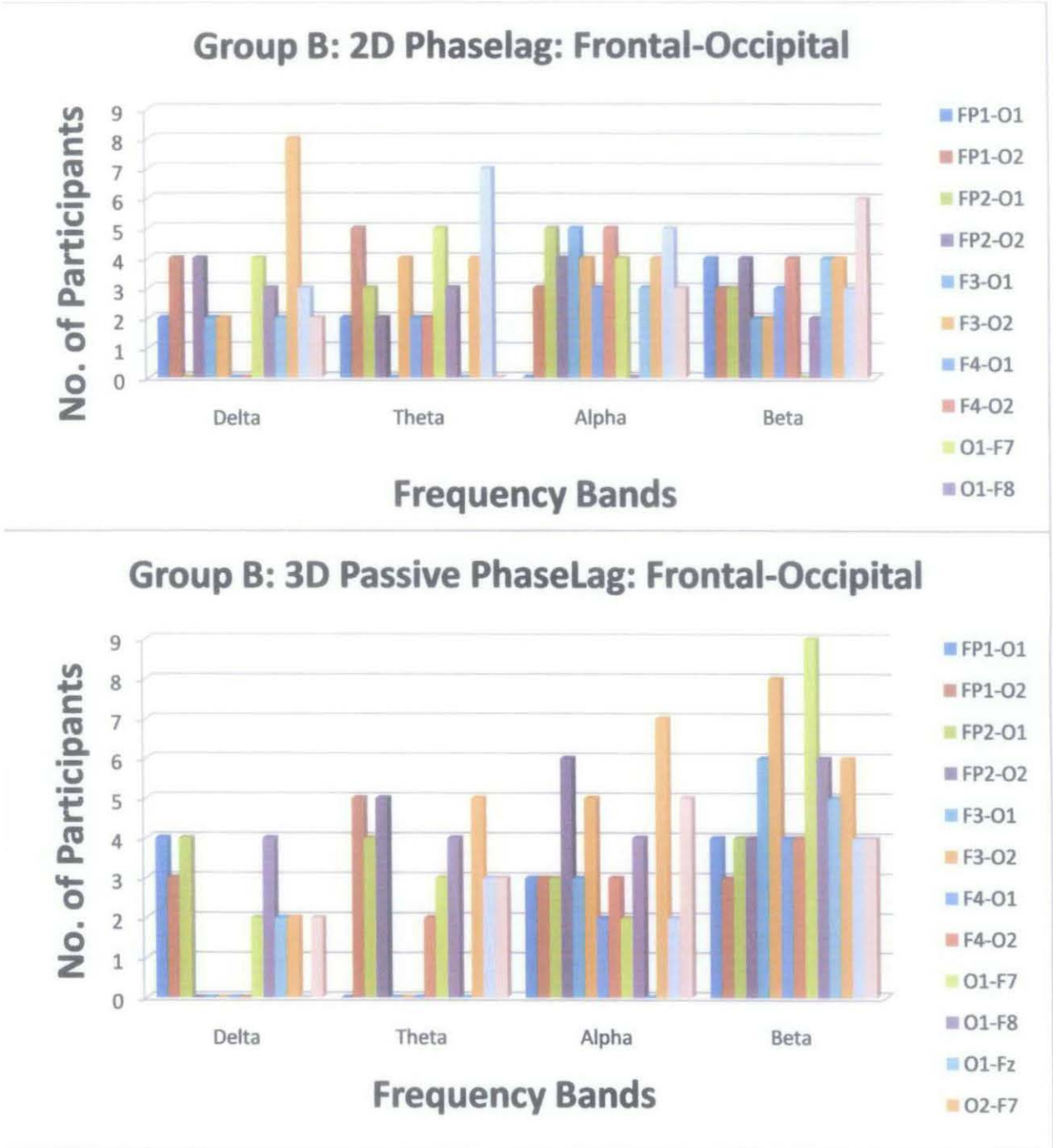


Figure 4.10: Group B Phase: Frontal - Occipital

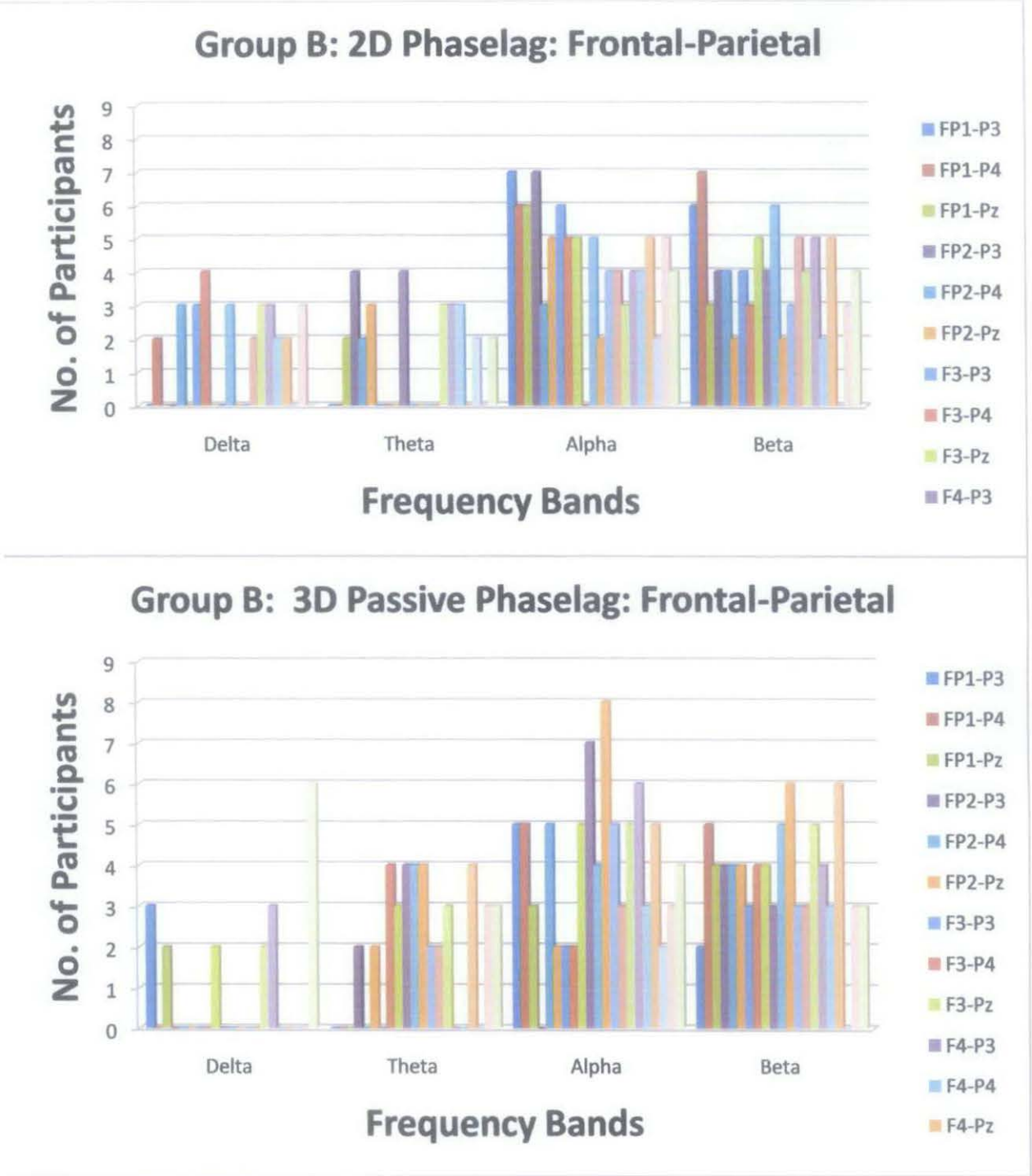


Figure 4.11: Group B Phase: Frontal - Parietal

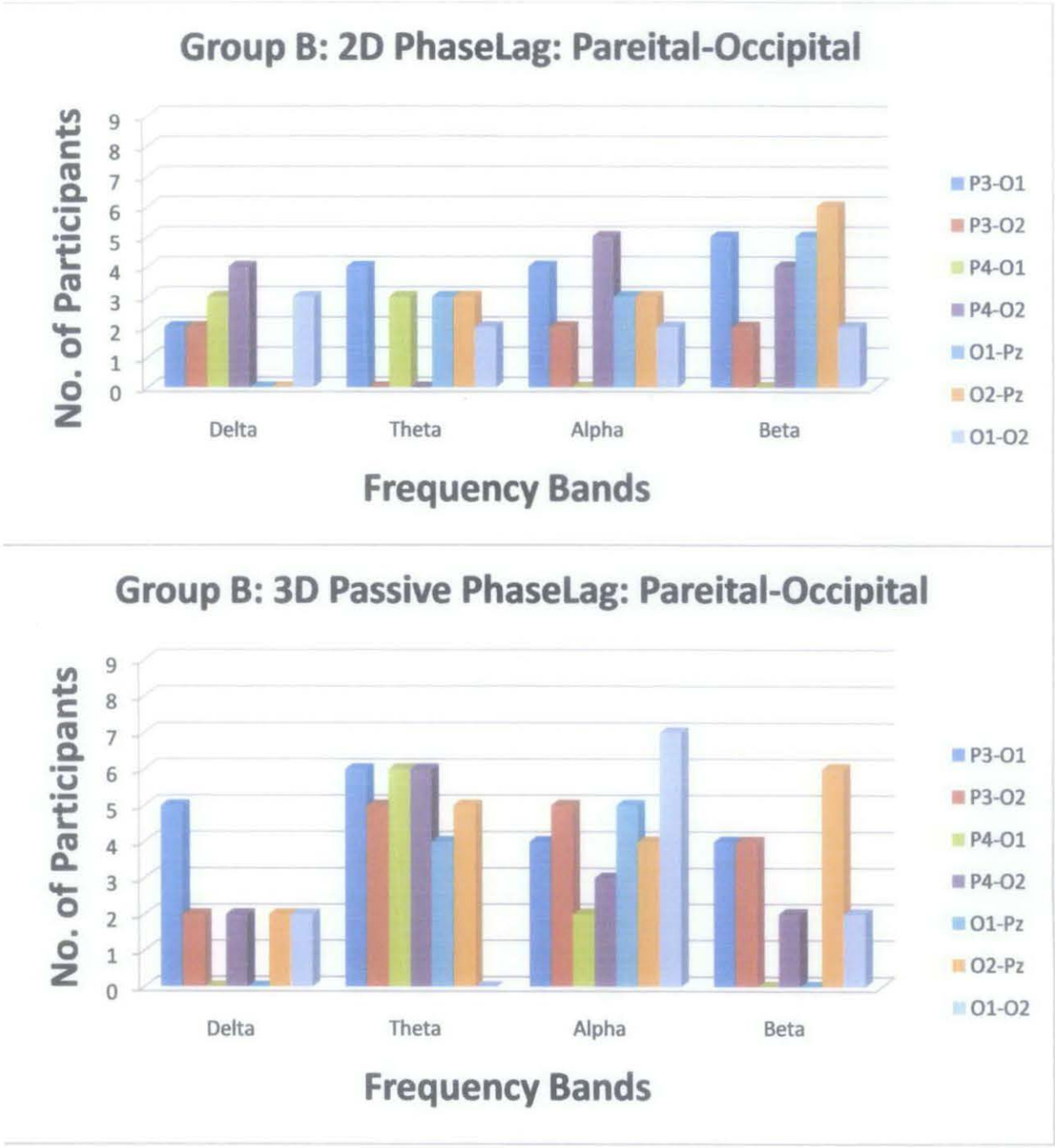


Figure 4.12: Group B Phase: Parietal - Occipital