Project Title: Keyboard-less system using EEG Signal

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Course: Final Year 2

Program: Electrical & Electronic Engineering

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18046

Dissertation submitted in

the requirements for the

Bachelor of Engineering (Hons)

(Electrical & Electronic Engineering)

JAN 2017

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CERTIFICATION OF APPROVAL

Keyboard-less system using EEG Signal

By

Najihah Abd Razak

A project dissertation submitted to the
Electrical & Electronic Engineering Department
of Universiti Teknologi PETRONAS
in the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved by,

____

(Dr.Nidal Kamel Selman**)**

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

May 2016

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.

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Najihah Abd Razak

ABSTRACT

Brain-computer interface is a technology that allow human who suffer from locked-in syndrome to control the computer or other devices to perform the desired task as their communication platform. The aim of this project is to develop a key board-less system using EEG signal for locked-in people to allow them to perform desired simple task such dialing a phone number. A healthy five male students aged between 22-25 years old will participate in the study. Each subject required to think about desired number of 0-9 on the screen that displays randomly. To identify the desired number, the brain response is recorded using EEG equipment. The recorded signal is then processed to remove biological artifacts using a toolbox in Matlab for EEG known as EEGLB©. After that, feature extraction takes place by calculating the average power correspondent to each number ab. The hypothesis for this study, the desired number will have a significant change in term of average power.

The goal of this study is to develop EEG-based phone dialling system for locked-in people that help them to dial phone numbers and make calls.

ACKNOWLEDGEMENT

The author would like to express a special appreciation to the supervisor, Dr. Nidal Kamel Selman; lecturer of Electrical & Electronic Engineering Department, Universiti Teknologi PETRONAS for his guidance throughout this project. Thank you for the continuous supports and motivation. Special appreciation is given to the doctorate student; Dr. Hossam Sayel Almahasneh for his guidance in preparing and conducting of the experiments as well as in analyzing the experimental results. Thank you for helping along the whole duration of the study as well as for the motivational support.

A heartfelt appreciation is extended to the CISIR technicians and staffs for their assistance to the author throughout the whole duration of the study. This study would have been a failure without their constant help in solving problems and errors faced by the author during the experiments.

To Universiti Teknologi PETRONAS, thank you for the opportunity given to the author to conduct a research study for this final year project. The author had received an opportune chance in meeting many wonderful people along the way of completing this project.

To my family, thank you for your prayers and moral support. And last but not least, millions of thanks to the lecturers, technicians and friends who have been contributing for this project indirectly.

Thank you.

Najihah Abd Razak

Electrical & Electronic Engineering Department

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CHAPTER 1

1.0 Introduction

Individuals with locked-in syndrome can't move their lower confront, bite, swallow, talk, move their appendages, or move their eyes from side to side. They may experience issues breathing, however, can see and listen. The disorder takes after stupor or coma since individuals have no undeniable method for reacting despite the fact that they are completely cognizant [1]. However, most can move their eyes here and there and blink. In the event that guardians don't see the eye developments, individuals with the locked-in syndrome may erroneously be thought to be unconscious of their surroundings and not able to think or convey. Individuals with the locked-in syndrome can figure out how to communicate using a computer input device controlled by eye developments. Different devices can recognize when individuals sniff somewhat. These devices can likewise be associated with a computer and used to communicate. Language instructors can individuals build up a correspondence code using eye blinks or sniffs. On the off chance that they recoup utilization of another body part, for example, a thumb or the neck, they can communicate in different ways [1]. One of the medical approaches to help locked-in people to communicate is by using a non-invasive technique known as electroencephalograph (EEG). Electroencephalography is a popular method for a non-invasive technique for recording the signals generated from the brain using a multiple number of electrodes placed on the scalp of the patient. This signal occurs when the spikes generated from neuron causes neurotransmitter to be released at synapse causing postsynaptic potentials within dendrites [2]. Around cerebral cortex is where EEG captures electrical activity. However, EEG is easy captures undesired signal generated by the brain as every movement will cause our brain to response hence giving the signal that also being captured by EEG. For example, eye movements, eye blinks, eyebrow movements, talking, chewing and head movement etc. will give an additional signal to EEG for it to capture. Our aim for this experiment is to develop EEG-based phone dialing system and to validate the developed system with a sufficient number of subjects.

The way to perform this task, the subject is required to wear EEG cap that consists multiple of electrodes. A conductive gel will be inserted into the hole of electrodes to have better conduction. The area that responsible for decision making is prefrontal lobe and frontal lobe [3]. Hence, with this advance medical care and communication technology may enable the locked-in people to do a simple daily task that will give a huge impact to the patient [4].

1.1 Problem Statement

A patient who suffers from locked-in syndrome is not able to communicate physically due to complete paralysis in almost all muscle movements except for the blinking and the movement of the eyes. However, the individual is aware of the surrounding and able to communicate through the movement of the eyes. This condition has held the individual to perform simply desired task. Hence, a simple approach to developing EEG-based phone dialling system for locked-in people as a communication platform is proposed. This system will help the locked-in individual perform simply desired task as it only requires brain signals as the commands without using any muscle movements.

1.2 Objectives

- ❖ To investigate the capability of the EEG to detect desired numbers among random numbers.
- ❖ To develop EEG-based phone dialling system for locked-in people

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1.3 Scope of study

The scope of this study is to investigate the EEG-based BCI that designed to help locked-in people communicate with others by means dialling a number and to develop a virtual number-dialing system for locked-in people. This system will use the EEG signal as an input command.

CHAPTER 2

LITERATURE REVIEW

2.0 Background

The interpretation of brain waves is an encoded signal derived from the brain to perform the desired task. These brain activities produce voltage fluctuations in the brain from ionic flow within neurones and being captured via electroencephalogram (EEG) that produces electrical activity throughout the brain[5]. It has frequency bands of 5: delta (0-4Hz), theta (4-8Hz), alpha (8-12Hz), beta (12-30Hz) and gamma (30-100Hz), as in figure X brain waves samples with frequency band. During both an active and resting state triggers its natural wave behaviour. However, any external movements can elicit these waves. Each frequency oscillation contributes to different cognitive functions determined by brain area [6].

Delta waves

This band is produced in profound rest state where it suspends its condition of mindfulness that empowers mending and recovery prepare. Delta waves have a normal for having high sufficiency and low frequency. This band is typically connected with the rest moderate wave. It is watched that the delta waves describe the onset of profound rest stages (organise 3 and stage 4) in sound grown-ups. Moreover, the pollution in EEG signal because of eye movement is for the most part spoken to in the delta frequency band

Theta waves

Theta waves (4-7Hz) commonly takes place in the processing the memory. Theta actuation is related in both cortical and hippocampal regions [7]. Considers demonstrating that theta waves may impact the way toward building recollections which assume a part in the capacity of short-term memory that noticeable in the hippocampus [7]. It is also been assumed that the cortical theta oscillations reflect the communication – a region that exhibit theta range oscillation [8].

Alpha waves

Alpha wave is at the frequency of 8-13Hz that located around cortex, occipital lobe, and thalamic regions. These waves are neural wavering that regularly recognised via EEG [9]. Alpha waves have a normal for large amplitudes and happen amid direct levels of mind action where the people briefly sit without moving yet alarm with the encompassing [9]. The cognitive performance of retrieving information from memory also corresponds with an Alpha brainwave. Alpha wave facilitates working memory and improves word recognition in older adults. Other than intellectual advantages, augment in the action of alpha waves likewise connected with an expanded view of placidness [6].

Beta waves

The frequency range of beta wave is between 12-38Hz that take place in an elevated state of awareness. At this express, the cerebrum wavering happens with a full fixation that happens in the motor cortex amid isotonic withdrawals and moderate developments that recognised by EEG [6]. This brainwave activation is connected with effective in scholastic execution as an addition in beta activation will prompt to the capacity of math estimation [10]. Aside from cognizance aptitudes, these brainwaves have additionally been appeared to influence temperament and feelings. This can be clarified when transcranial attractive beta wave stimulation has demonstrated a critical diminishing in enthusiastic weariness and state uneasiness [5].

Gamma waves Gamma waves occur at the frequency range between (30-100Hz) that involved with conscious attention. Inquire about demonstrated gamma wave starts from thalamus and will move anteriorly as they are enacted to synchronise neuronal activity [5]. Gamma wave at the recurrence of 40Hz is connected with neuronal hardware. It has been noticed that the nonattendance of this wave because of thalamic injury will bring about the oblivious mindfulness and the individual will slip introduction significant unconsciousness [5].

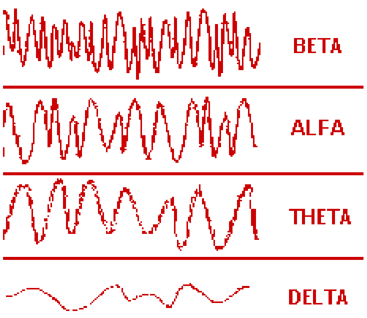

Figure 1: The dominant brain frequency

Electroencephalograph (EEG)

EEG recording is partitioned into two sorts: spontaneous activity (SA) and event-related-potentials (ERP) or evoked potential (EP). The meaning of spontaneous activity in the sensory system is a neural activity that is not driven by an outside boost and is viewed as an issue for tactile preparing and calculation. SA has a bandwidth frequency range between 0-100Hz. On the other hand, ERP is characterised as time-bolted reactions of particular frequency after incitement can be distinguished by registering the amplitude frequency characteristics (AFC) of the averaged ERP by averaging number of trials to enhance the signal-to-noise ratio (SNR) [11]. Flag preprocessing is essential to amplify the SNR since there are many clamour sources experienced with the EEG signals. The sources of noise can be any form such as eye movement, muscular activity etc. EEG cap is used to measure the brain activities by placing on the scalp of the patients using conductive paste or gel. EEG cap consists of multiple of the electrode associated with each region that carries different brain activity [11].

EEG recording system consists of four parts which are electrodes with conductive media, amplifier with filters, A/D converter and recording device [11]. Firstly, there is two type of conductivity that may affect the result: dry or wet depends on the requirement to use the conductivity of electrodes. To enhance the signal to digitise accurately by in increase the low magnitude signals, an amplifier is used. The preparation of the subject, generally cleaning the skin surface with hair spray or hair gel is recommended. If anything left on the skin surface while extracting the signal, the results may vary due to any chemical left on the skin. That is why it is important to practice the proper hygiene and safety protocol. The electrodes consist of silver chloride and the space between the scalp and the electrode need to fill with conductive paste or gel. With the cap systems, there is a little opening to infuse conductive paste. Conductive paste and conductive jam serve as media to guarantee to bring down of contact impedance at the electrode-skin interface [11].

In 1958, International Federation in Electroencephalography and Clinical Neurophysiology has thought of standard electrode placement known as "10-20" electrode placement to standardise the assignments and physical placement of the electrodes on the scalp [11]. The coverage of the electrodes is divided into an equivalent distance from the top of the head called nasion spread until inion to provide sufficient coverage. The designation of "10-20" labeled accordingly: F (frontal), C (Central), T (Temporal), P (Posterior) and O (Occipital) [11]. At that point, the numbering of every assignment begins with an odd number at the left half of the head and with an even number on the correct side of the head as shown in Figure 2.

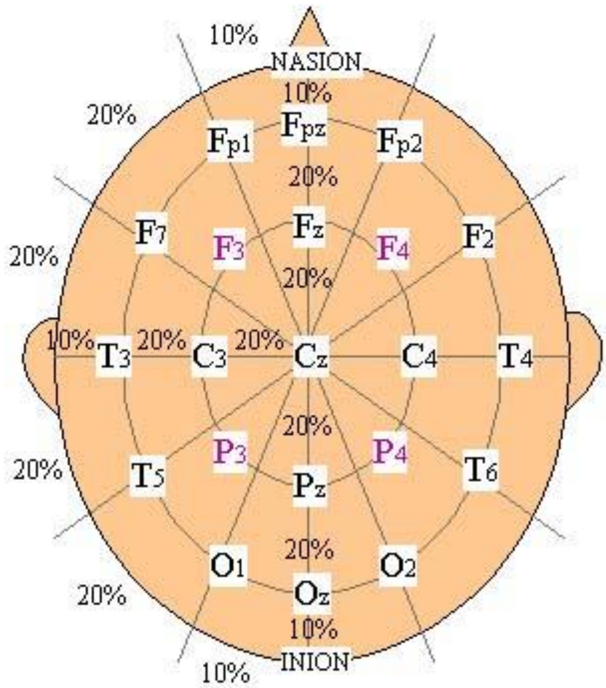

Figure 2: The Placement of Electrode of 10-20

The amplification of the signals is required to ensure the compatibility of the devices such as A/D converter, displays or recorders. The requirement of amplifiers to measure these signals is needed [11]. Amplifiers adequate to measure these signals have to satisfy very specific requirements. The A/D converter is interfaced to a PC framework so that every example can be spared in the PC's memory. The resolution of the converter is dictated by the littlest adequacy that can be examined. This is gotten by isolating the voltage scope of the A/D converter by 2 raised to the force of the number of bits of the A/D converter [11].

Event-Related Potentials

The significant changes of voltage's fluctuations due to elicit neural activity triggered by external or internal impulse are known as Evoked Potentials or Event Related Potentials (ERP) [11]. ERP is reasonable for concentrate both of the part of subjective ordinary or irregular nature: neurological or psychiatric disorders. Mental operations, for example, those included in recognition, specific consideration, dialect handling, and memory, continue after some time goes at the request of many milliseconds. ERP ready to characterise the initiation time while PET and MRI ready to confine areas of enactment amid mental [11]. The difference of amplitudes between ERP and spontaneous EEG components is that ERP has smaller amplitudes than EEG, so they cannot be traced from raw data. The extraction is carefully averaged of epochs (recording periods) of EEG time-locked to rehashed events of tangible, psychological or engine occasions from an arrangement of single recordings [11]. The unconstrained voltage fluctuations which happen generally irregular to the time moment that the stimuli happened arrives at the midpoint of out leaving the ERP of the brain. These outcomes reflect just the region where reliably connected with the preparing of the stimulus in time-bolted. At last, ERP reflects with high transient resolutions, the examples of neuronal action evoked by stimulus[11].

The basic signal processing tools for P-300 based BCI where the location of electrodes typically exploited over the parietal lobe [11]. The evoked potential by the oddball pattern of P300 is represented by repeated stimuli to the subject and has a target stimulus that once in a while happens among all the regular stimuli. Every time the objective stimulus is displayed to the client, the P300 reaction shows up in the EEG signals [11]. Although the P300 response is known to occur with different forms of stimuli, such as auditory stimuli, these experiments only use flashing visual stimuli. The low signal-to-noise-ratio is one of the challenges of P300 classification. The difficulty of P300 response is to differentiate between background noises due to ongoing electrical activity in the brain. Therefore, to overcome low SNR by averaging many subsequent trials [11].

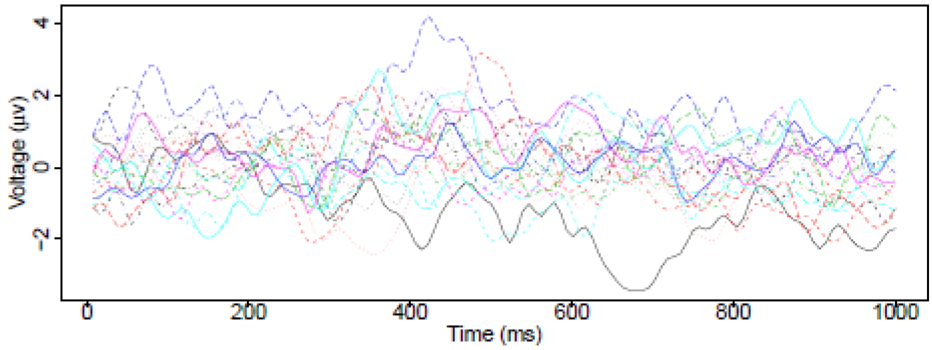

Figure 3 shows 20 individual targets P300 trials, and it is clear to see how much noise is included in single trials and how difficult it is to find the true P300 signal.

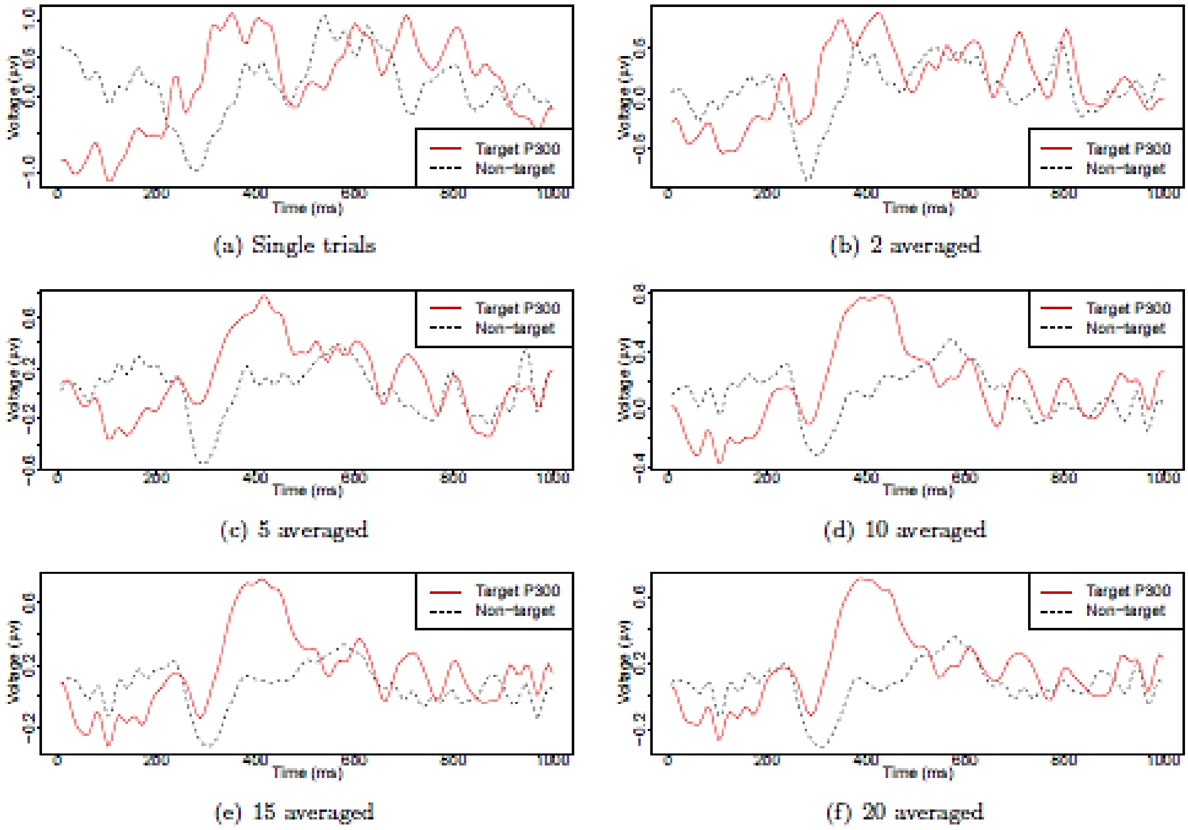

Figure 4 this plot shows the effects of averaging trials together. The same 20 target trials from Figure 3 are averaged together and shown with 20 non-target trials. As more trials are averaged together from (a) - (f), the distinction between target and non-target trials is made clearer.

EEG signal processing principle

In BCI design, EEG flag handling goes for making an interpretation of raw EEG signals into the class of these signals, i.e., into the assessed mental state of the client. This interpretation is normally accomplished utilising an example acknowledgement approach, whose two principle steps are the accompanying:

- Feature Extraction: The first flag preparing step is known as "feature extraction" and goes for depicting the EEG motions by (in a perfect world) a couple of significant qualities called "features". Such features ought to catch the information implanted in EEG flags that is significant to depict the mental states to distinguish while dismissing the commotion and other non-pertinent information. All features removed are typically organised into a vector, known as a feature vector. With BCI, there are 3 fundamental wellsprings of information that can be utilised to concentrate features from EEG signals: spatial information, spectral information, and temporal information.
- Classification: The second step, signified as "classification" allows a class to a set of features (the feature vector) removed from the signals. This class relates to the sort of mental state recognised. This progression can likewise be indicated as "feature translation". Classification algorithms are known as “classifiers”.

Oscillatory activity-based BCI is based on a change in power in some frequency bands, in some particular brain regions. There are numerous approaches to figure band power highlights from EEG signals. Be that as it may, a straightforward prevalent and proficient on is to first band-pass channel the EEG signal from a given channel into the frequency band of intrigue, then to square the subsequent signal to register the signal power, lastly to normal it after some time.

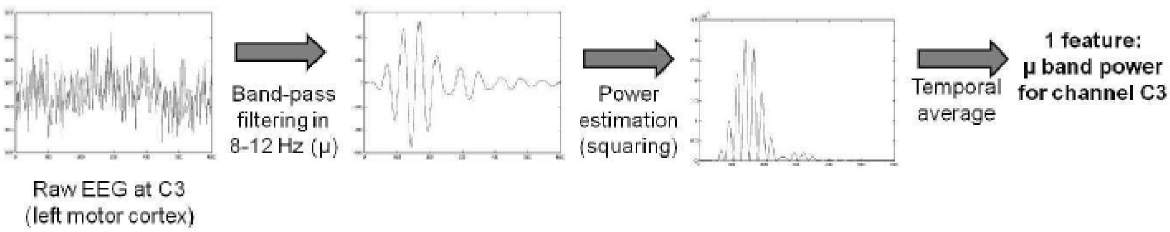

Figure 5: Steps of signal processing from the extraction of power features

Independent Component Approach (ICA)

Multichannel recordings of the electromagnetic fields rising up out of neural streams in the mind produce extensive sums of information. Reasonable element extraction techniques are, in this manner, helpful to encourage the portrayal and translation of the information [12].With the presence of new anatomical and common sense imaging procedures, it is as of now possible to assemble boundless measures of data from the brain. It has accordingly turned out to be imperative to remove the basic components from the information to permit a less demanding portrayal or elucidation of their properties[12].

Conventional ways to deal with illuminate this element extraction or measurement decrease issue include principle component analysis (PCA) and independent component analysis (ICA) which is used on a novel signal processing technique. In this preprocessing method, ICA is a novel factual system that goes for finding direct projections of the information that augment their mutual independence. Feature extractions and blind source separation (BSS) are the main applications that focus more on physiological data analysis and audio signal processing [12].

Identification of artifact removal of EEG has a lot of dealing with plenty of artifacts that may provide a valuable piece of information that may be difficult to extract [12]. The artifact's amplitude can be easily recognized when the size of artifact's amplitude is half of the size of brain signals that may mask the activity of the brain. There are also resemblances of an artifact to the neural responses that the interpretation of artifact data may mislead. An example of artifacts such as movement of the muscles, movement of the eyes and the disturbance of magnetic [12].

CHAPTER 3

METHODOLOGY

3.0 Data Collection

The data were recorded from healthy five male students aged between 22-25 years old. The subject requires remaining calm for 10 minutes with eyes closed before the experiment begins and remaining in a passive state with no movement. The subject will be trained to do the tasks many times. The tasks performed are:

Task 1: The subject required to clear their mind, remain calm by closing their eyes.

Task 2: The subject required to think a desired number beforehand.

The device that will be used on the subject is EEG cap that will be placed on the scalp of the subject. Before that, it is required for the subject to not have any hair gel or hair conditioners before the experiment begin. The “10-20” EEG cap consists of multiple electrodes to measure the electrical potential generated by brain activity. Each electrode consists of wire attached to the scalp using a conductive gel or paste. The data acquisition will be performing using BrainMaster at 200 samples per second sampling frequency. The area where decision making mostly in the frontal and prefrontal cortex. Therefore, there will be seven electrodes;, FP1 and FP2, in prefrontal lobe, and F7, F3, FZ, F4 and F8 in the frontal lobe.

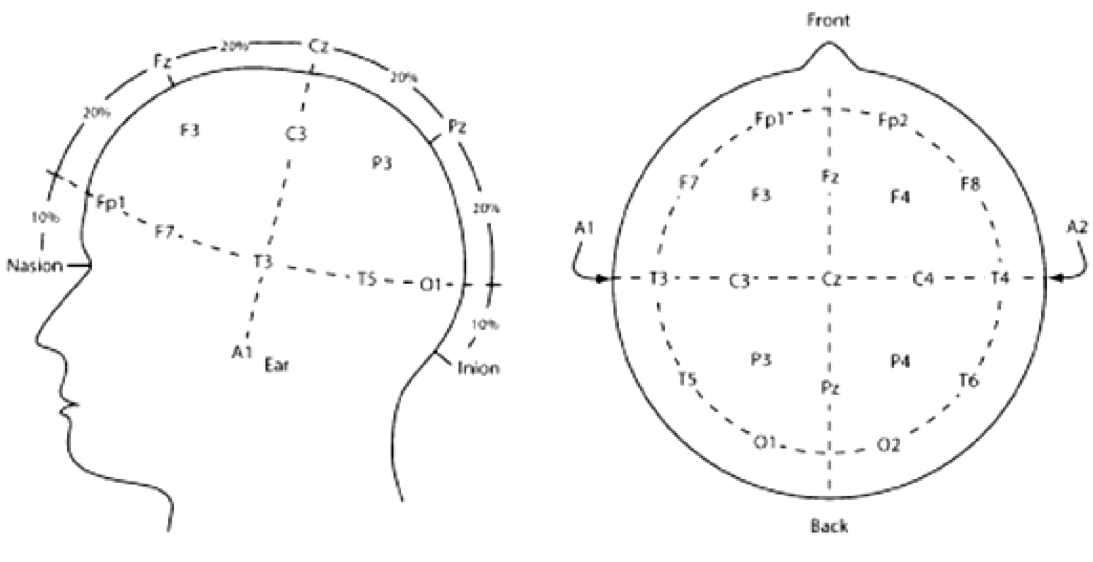

Figure 6: The Placement of Electrode of 10-20

Experiment Design

The participants sat on the chair facing the screen computer. The number was randomly projected on the screen and EEG recording took place during the session. Each session was held approximately 20 minutes per participant. Before the experiment began, the participants were required to practice as mention in the data collection. The stimulation displayed fixation screen for 5s first then displayed the numbers of 0-9 for 10s each number and after the last displayed number was a white blank screen for 120s to indicate the end of the session. The display numbers was repeated randomly for 10 times. After running a few trials, the experiment began. The EEG recording took place as participants instructed to pay full attention to the random number projected on the screen and when the desired number appears, the desired command takes place. Figure 7 shows an illustration of the stimulation of displaying the numbers. Figure 8 shows experiment being conducted.

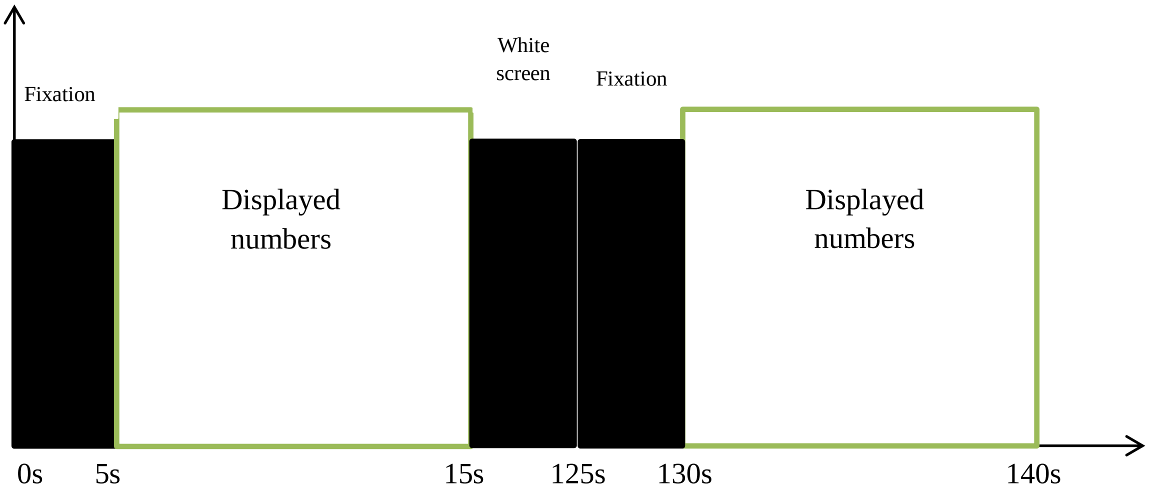

Figure 7: Illustration of the stimulation of displaying the numbers

Figure 8 shows experiment being conducted.

3.1 Preprocessing EEG Signals

The raw data from EEG signals has been processed by removing artifacts such as eye blinking, muscle artifact and movement artifact [13]. The downsampling will be done from 500-250 and band pass filter from 0.5Hz to 50 Hz. Artifact removal using Independent Component Analysis (ICA).

3.2 Feature Extraction

The raw data of EEG signal is time domain and the features are concealed in the noise. Keeping in mind the end goal to separate the features, the EEG signal is broke down to give a portrayal of the signal vitality as a component of recurrence or time. In light of past reviews, the best to perceive the mental tasks in light of EEG signals is separated in recurrence domain [14].

Fast Fourier Transform (FFT) is the first analysis method by applying discrete Fast Fourier Transform to the signal and finds its spectrum. The EEG signal characteristics of the acquired EEG signal to be analyzed are enlisted by power spectral density (PSD) estimation in demand to explicitly address the EEG tests signal.

The PSD is discovered by Fourier changing the assessed autocorrelation progression which is found by nonparametric strategies [15]. The equation expression:

$$X_i\,(n) = x\,(n+iD), \qquad n = 0, 1, 2,\ldots\ldots, M-1 \qquad (1)$$

$$\text{While } I = 0, 1, 2,\ldots\ldots, L-1;$$

Take to be the reason for the start of the arrangement. By then of length 2 speak to data partitions that are surrounded. The coming to fruition yield period grams give

$$U = \frac{1}{M} \sum_{n-1}^{M} x[\mathrm{n}]^2$$

$$\text{Average power of one second} = \frac{1}{250} \sum_{n=1}^{250} x[\mathrm{n}]^2$$

The hypothesis for this project is that a desired will have significant changes in terms of average power.

No	Details	Week														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Data Acquisition															
2	Preparation of progress report															
3	Submission of Progress report															
4	Continuation of analysis of the data															
5	Pre-Sedex															
6	Finalize of project work															
7	Submission of draft report															
8	Submission of final report and technical report															
9	FYP 2 Viva															

Figure 9: Gantt chart

Planning

Key Milestone

CHAPTER 4

RESULTS & DISCUSSION

In this chapter discuss the experiment end result that has been performed and analyzed the information therefore with methodology steps which have been cited in chapter 3. This chapter is separated into several factors to reveal the implementation and analysis process as a result.

Decision-making area

The brain is separated into frontal and prefrontal cortex that is accountable for the decision-making technique. The experiments carried out with seven electrodes positioned on the scalp of the subject with the respected regions to capture brain activity. Consequently, there are seven electrodes; FP1 and FP2, in prefrontal lobe, and F7, F3, FZ, F4 and F8 within the frontal lobe.

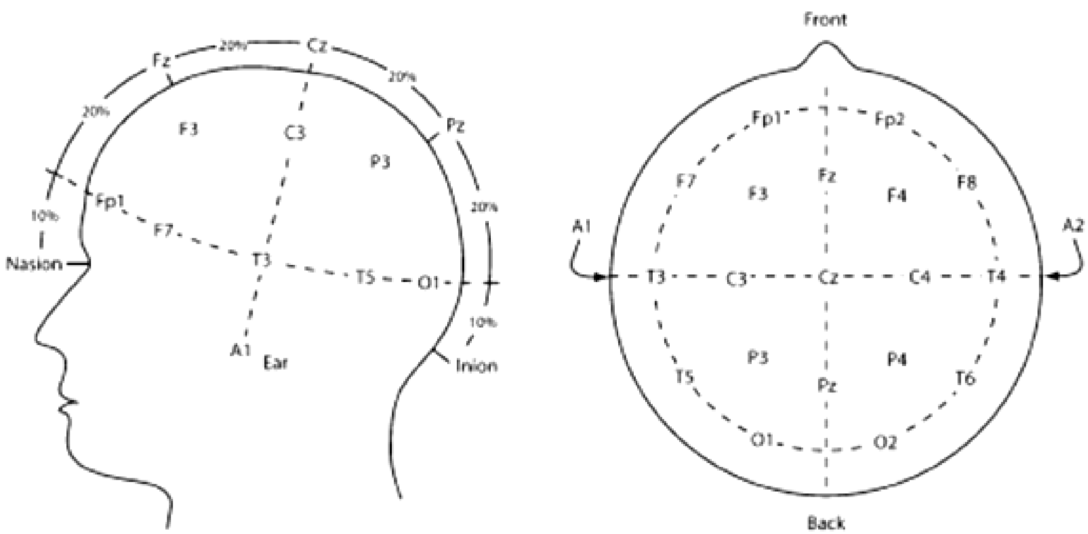

Figure 10 Electrodes placement in decision-making area

Data Acquisition

The information obtaining wound up plainly finished by means of the utilization of BrainMaster on 5 subjects with the equivalent foundation of the review. There had been 10 back to back trials for each subject and each of them required to consider the favored number ahead. Every trial, the number being shown zero-9 digits and just a single might be the favored number. The information of each compare subject has been recorded. The following is the coveted number for each subject for 10 trials.

Table 1: Desired number for each subject

	Desired Number				
	Subject				
No. of trials	1	2	3	4	5
1	4	7	3	7	2
2	6	5	1	8	8
3	2	1	8	3	1
4	8	3	2	1	9
5	7	9	4	5	5
6	1	0	9	2	0
7	5	2	7	4	7
8	3	4	5	6	4
9	0	6	0	0	6
10	9	8	6	9	3

Once the raw data obtained, the first step in pre-processing the data is to down sample from 500 to 256 sampling rate and filter the data from 0.5 to 50 Hz. Lastly, independent component analysis (ICA) is applied on the signal. After applying ICA on the signals, artifact removal has been done to ensure there is no noise component in the data. The example of artifact removals such as eye blinking and muscle movement. After that, the data is ready to be analyzed.

Feature Extraction

After artifact removal technique has been performed, fast Fourier transform has been implemented to the signal into 3 correspond frequency alpha, beta, and theta. FFT converts the signals in a time domain into the frequency domain in which basically signals with time independent can be broken down into sinusoids wave. In each subject, it is divided into three bands; Alpha band, Beta band, and Theta band. In every band, the records have calculated the usage of FFT for every trial of 10 that represent 10 digit numbers. Therefore, a complete of 150 graphs has been generated and determined by the significant changes in phrases of 7 channels of EEG that correspond to decision-making area at the prefrontal cortex. In this section, displayed a total of 30 set of graph of each band consist of Alpha band, Beta band and Theta band respectively.

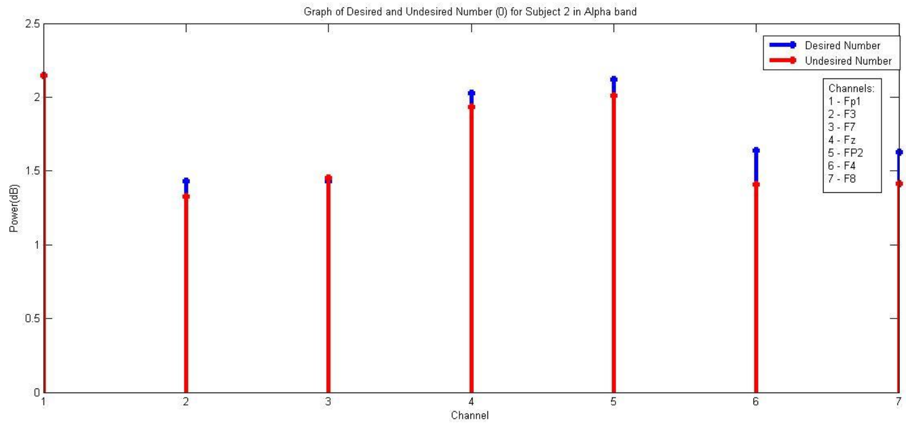

Figure 11 Graph of desired and undesired for the first trial in Alpha band for Subject 2

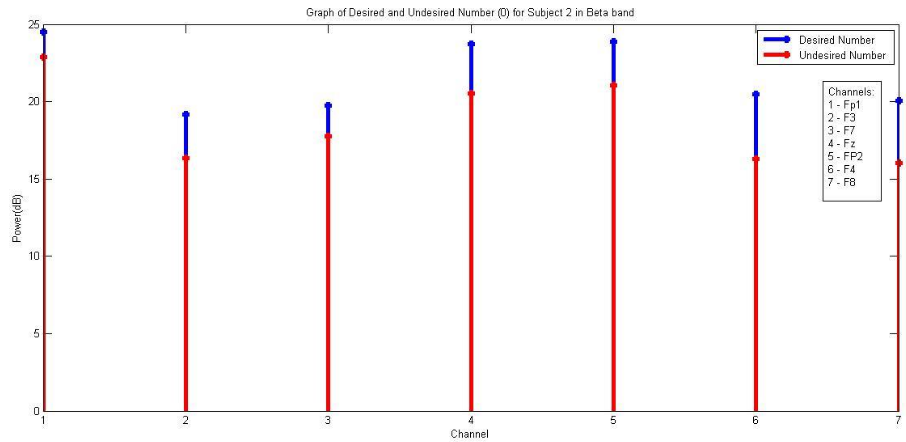

Figure 12 Graph of desired and undesired for the first trial in Beta band for Subject 2

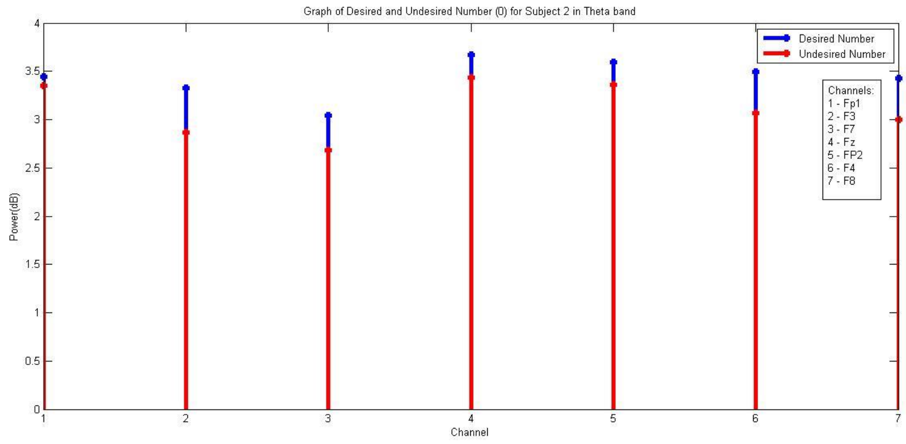

Figure 13 Graph of desired and undesired for the first trial in Beta band for Subject 2

The table below shows the average power calculated in each band for the first trial.

Table 2: Average power for the first trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.144513	1.325156	1.452358	1.933158	2.010239	1.405918	1.413836
Dalpha	2.144615	1.428003	1.431125	2.029386	2.121698	1.637238	1.629301
Unbeta	22.87508	16.3222	17.73056	20.54963	21.07701	16.28323	16.05218
Dbeta	24.4934	19.17221	19.75801	23.73556	23.85026	20.46833	20.0689
Untheta	3.352368	2.869321	2.679568	3.436074	3.362133	3.069394	2.996188
Dtheta	3.443251	3.323299	3.041146	3.668664	3.59307	3.495064	3.425608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has significant value is at channel 5 which is at FP2.

For the next trial with the same subject represents the average power with 7 electrodes with desired and undesired graph that have significant changes in power. The second trial represented in three graphs (alpha, beta and theta band) with the same subject that corresponds to the average power.

The second trial graph in each band representation with the same subject is shown below.

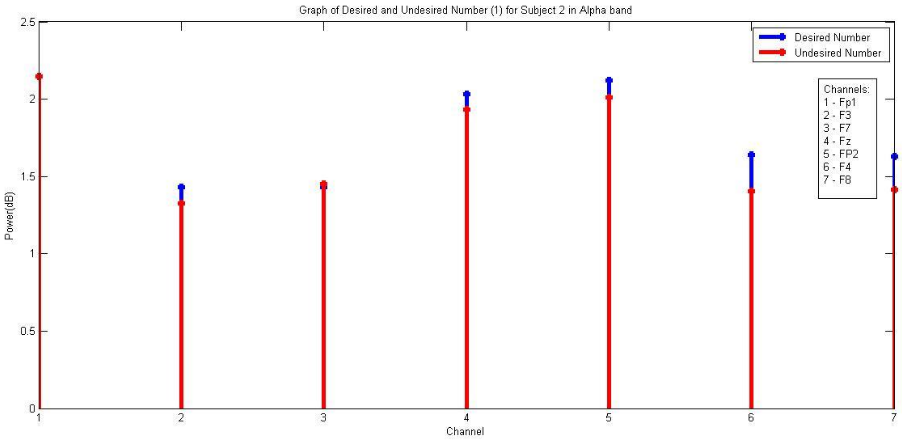

Figure 14 Graph of desired and undesired for the second trial in Alpha band for Subject 2

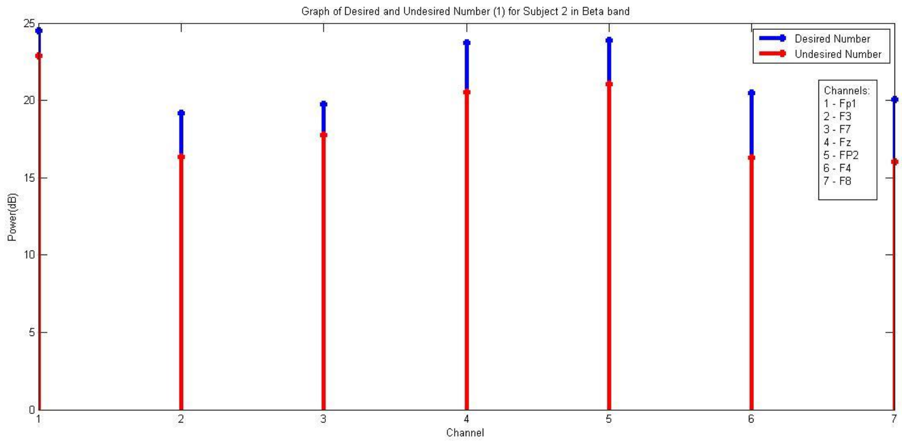

Figure 14 Graph of desired and undesired for the second trial in Beta band for Subject 2

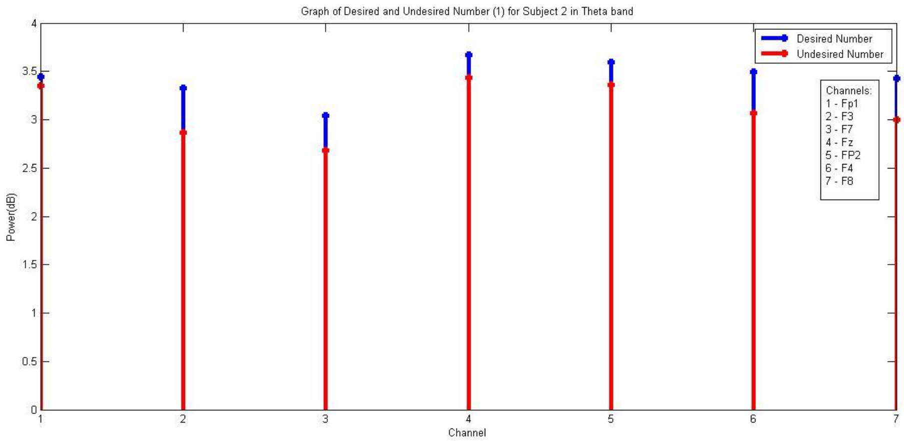

Figure 15 Graph of desired and undesired for the second trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the second trial.

Table 3: Average power for the second trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.144513	1.325156	1.452358	1.933158	2.010239	1.405918	1.413836
Dalpha	2.144615	1.428003	1.461125	2.029386	2.121698	1.637238	1.629301
Unbeta	22.87508	16.3222	17.73056	20.54963	21.07701	16.28323	16.05218
Dbeta	24.4934	19.17221	19.75801	23.73556	23.85026	20.46833	20.0689
Untheta	3.352368	2.869321	2.679568	3.436074	3.362133	3.069394	2.996188
Dtheta	3.443251	3.323299	3.041146	3.668664	3.59307	3.495064	3.425608

For the next trial with the same subject represents the average power with 7 electrodes with desired and undesired graph that have significant changes in power. The second trial represented in three graphs (alpha, beta and theta band) with the same subject that corresponds to the average power. Based on the graph shown above for the second trial, it is still showing same good significant changes that correspond to desired and undesired graph.

The third trial graph in each band representation with the same subject is shown below.

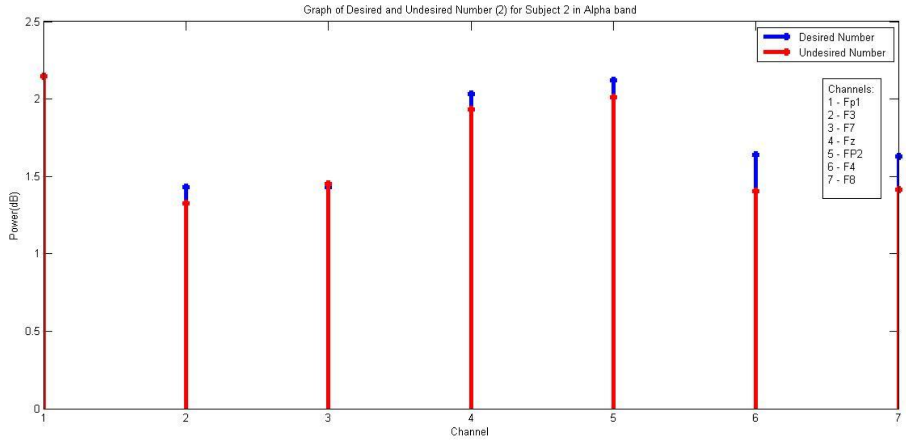

Figure 16 Graph of desired and undesired for the third trial in Alpha band for Subject 2

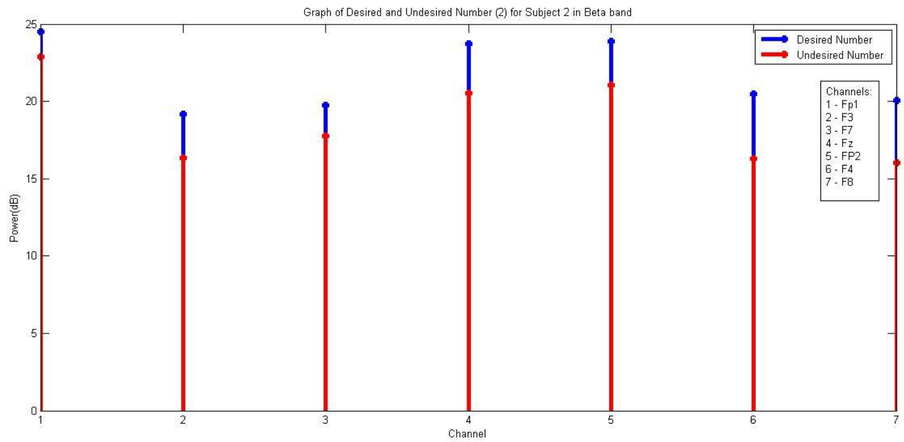

Figure 17 Graph of desired and undesired for the third trial in Beta band for Subject 2

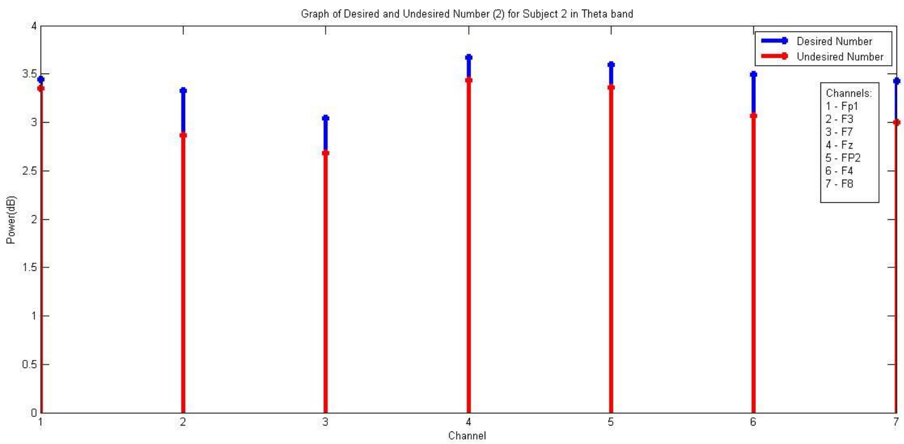

Figure 18 Graph of desired and undesired for the third trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the third trial.

Table 4: Average power for the third trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.144513	1.325156	1.452358	1.933158	2.010239	1.405918	1.413836
Dalpha	2.294615	1.428003	1.531125	2.029386	2.121698	1.637238	1.629301
Unbeta	22.87508	16.3222	17.73056	20.54963	21.07701	16.28323	16.05218
Dbeta	24.4934	19.17221	19.75801	23.73556	23.85026	20.46833	20.0689
Untheta	3.352368	2.869321	2.679568	3.436074	3.362133	3.069394	2.996188
Dtheta	3.443251	3.323299	3.041146	3.668664	3.59307	3.495064	3.425608

For the next trial with the same subject represents the average power with 7 electrodes with desired and undesired graph that have significant changes in power. The third trial represented in three graphs (alpha, beta and theta band) with the same subject that corresponds to the average power. Based on the graph shown above for the third trial, it is still showing same good significant changes that correspond to desired and undesired graph.

The fourth trial graph in each band representation with the same subject is shown below.

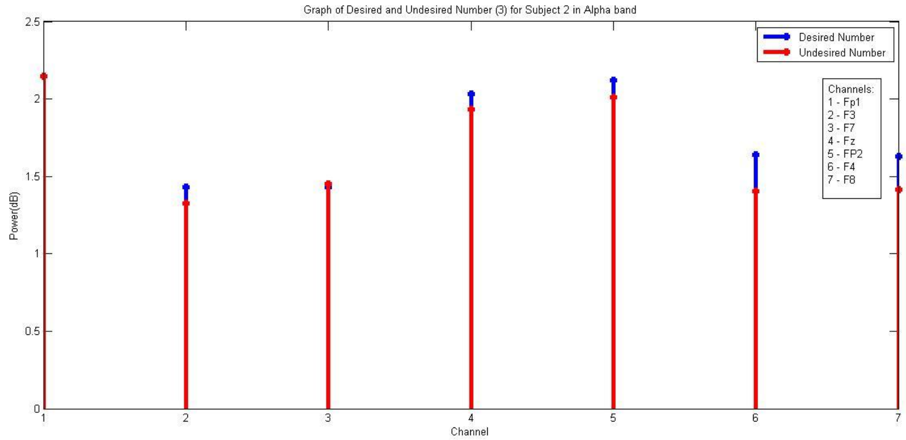

Figure 19 Graph of desired and undesired for the fourth trial in Alpha band for Subject 2

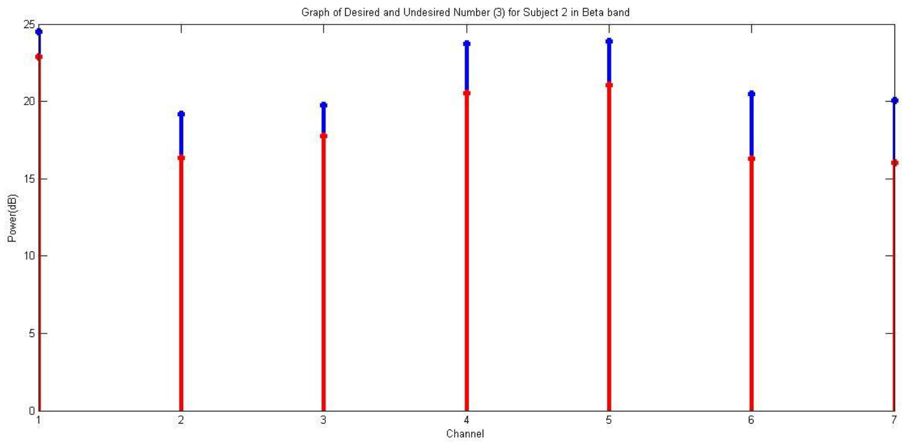

Figure 20 Graph of desired and undesired for the fourth trial in Beta band for Subject 2

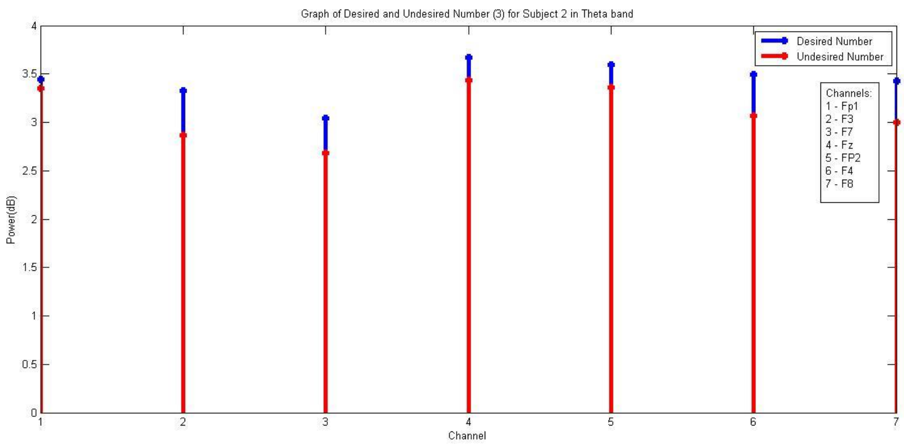

Figure 21 Graph of desired and undesired for the fourth trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the fourth trial.

Table 5: Average power for the fourth trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.144513	1.325156	1.452358	1.933158	2.010239	1.405918	1.413836
Dalpha	2.147615	1.458003	1.491125	2.029386	2.121698	1.637238	1.629301
Unbeta	22.87508	16.3222	17.73056	20.54963	21.07701	16.28323	16.05218
Dbeta	24.4934	19.17221	19.75801	23.73556	23.85026	20.46833	20.0689
Untheta	3.352368	2.869321	2.679568	3.436074	3.362133	3.069394	2.996188
Dtheta	3.443251	3.323299	3.041146	3.668664	3.59307	3.495064	3.425608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has still had the same significant value is at channel 5 which is at FP2. Based on the graph shown above for the fourth trial, it is still showing same good significant changes that correspond to desired and undesired graph in each band.

The fifth trial graph in each band representation with the same subject is shown below.

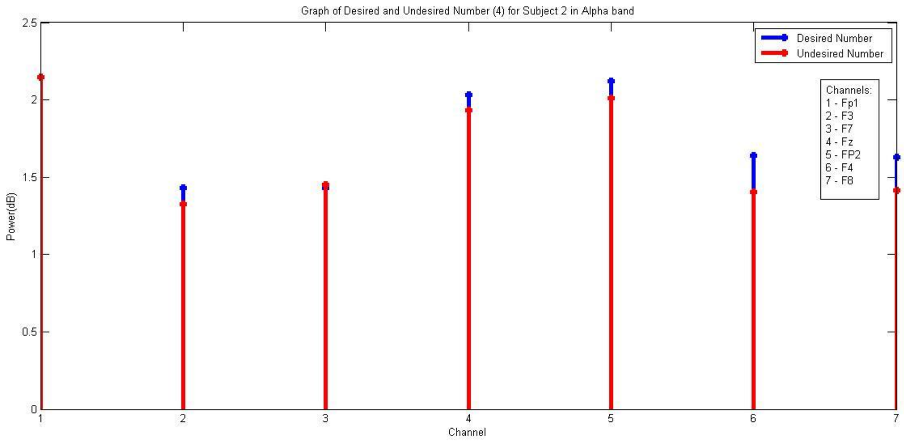

Figure 22 Graph of desired and undesired for the fifth trial in Alpha band for Subject 2

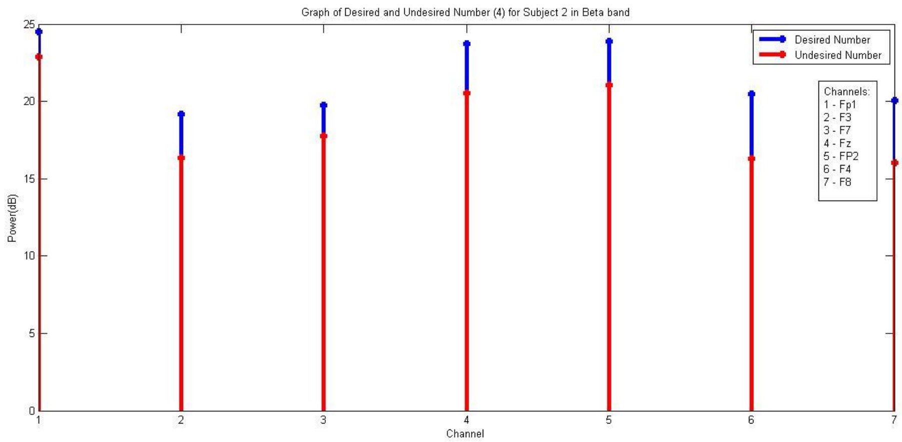

Figure 23 Graph of desired and undesired for the fifth trial in Beta band for Subject 2

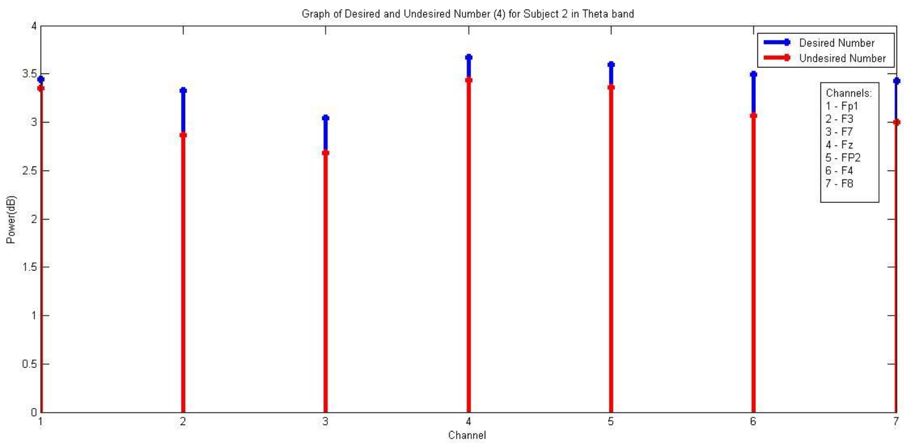

Figure 24 Graph of desired and undesired for the fifth trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the fifth trial.

Table 6: Average power for the fifth trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.134513	1.335156	1.452358	1.923158	2.010239	1.415918	1.413836
Dalpha	2.149615	1.438003	1.431125	2.039386	2.129698	1.637238	1.629301
Unbeta	22.89508	16.3222	17.73056	20.54963	21.07701	16.28323	16.05218
Dbeta	24.5934	19.17221	19.75801	23.73556	23.85026	20.46833	20.0689
Untheta	3.352368	2.869321	2.679568	3.436074	3.362133	3.069394	2.996188
Dtheta	3.443251	3.323299	3.041146	3.668664	3.59307	3.495064	3.425608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has still had the same significant value is at channel 5 which is at FP2. Based on the graph shown above for the fifth trial, it is still showing same good significant changes that correspond to desired and undesired graph in each band.

The sixth trial graph in each band representation with the same subject is shown below.

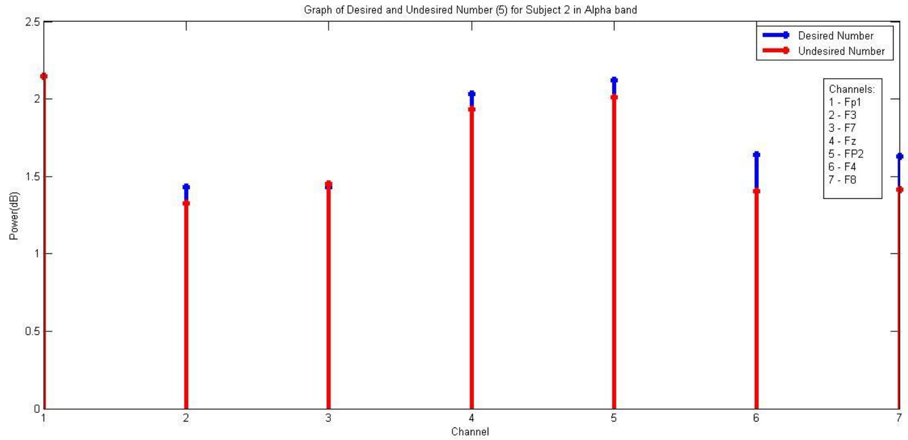

Figure 25 Graph of desired and undesired for the sixth trial in Alpha band for Subject 2

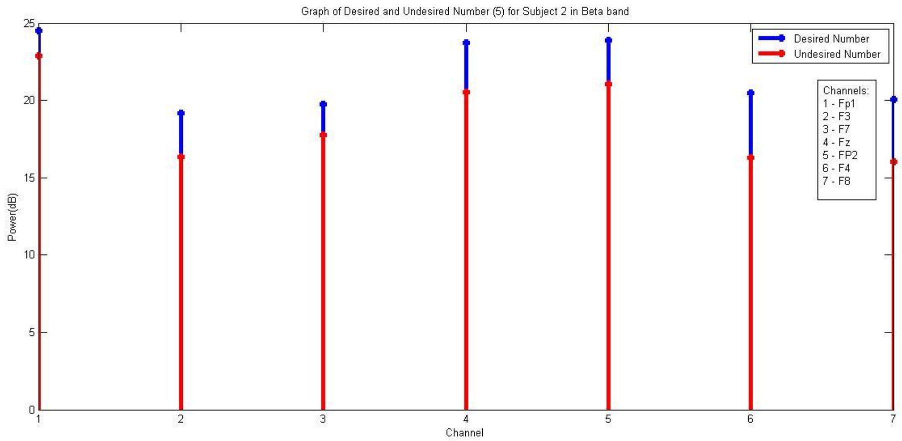

Figure 26 Graph of desired and undesired for the sixth trial in Beta band for Subject 2

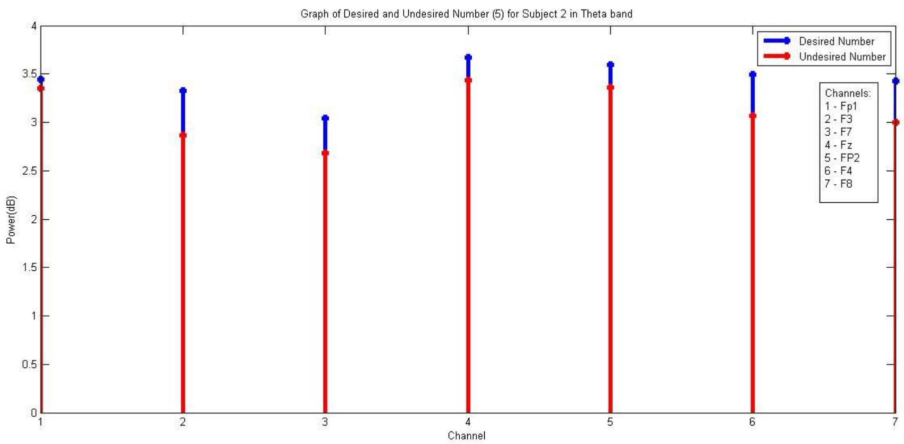

Figure 27 Graph of desired and undesired for sixth trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the sixth trial.

Table 7: Average power for the sixth trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.144513	1.325156	1.452358	1.933158	2.010239	1.405918	1.413836
Dalpha	2.154615	1.428003	1.491125	2.029386	2.121698	1.637238	1.629301
Unbeta	22.87508	16.3222	17.73056	20.54963	21.07701	16.28323	16.05218
Dbeta	24.4934	19.17221	19.75801	23.73556	23.85026	20.46833	20.0689
Untheta	3.352368	2.869321	2.679568	3.436074	3.362133	3.069394	2.996188
Dtheta	3.443251	3.323299	3.041146	3.668664	3.59307	3.495064	3.425608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has still had the same significant value is at channel 5 which is at FP2. Based on the graph shown above for the sixth trial, it is still showing same good significant changes that correspond to desired and undesired graph in each band.

The 7th trial graph in each band representation with the same subject is shown below.

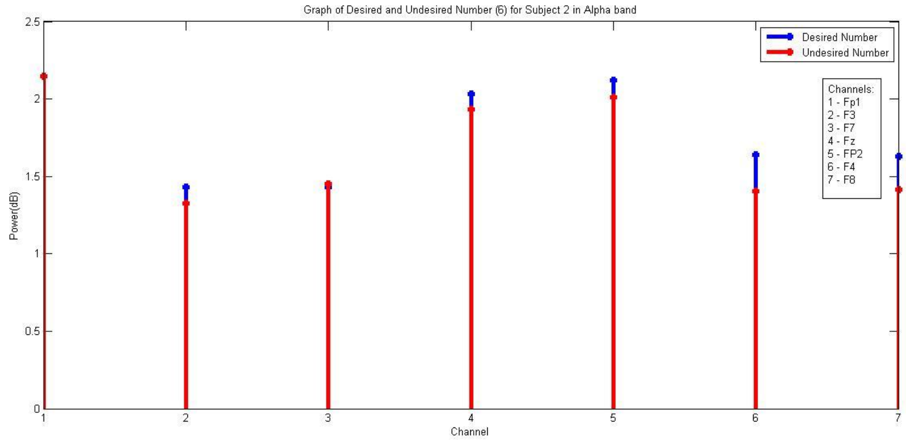

Figure 28 Graph of desired and undesired for the seventh trial in Alpha band for Subject2

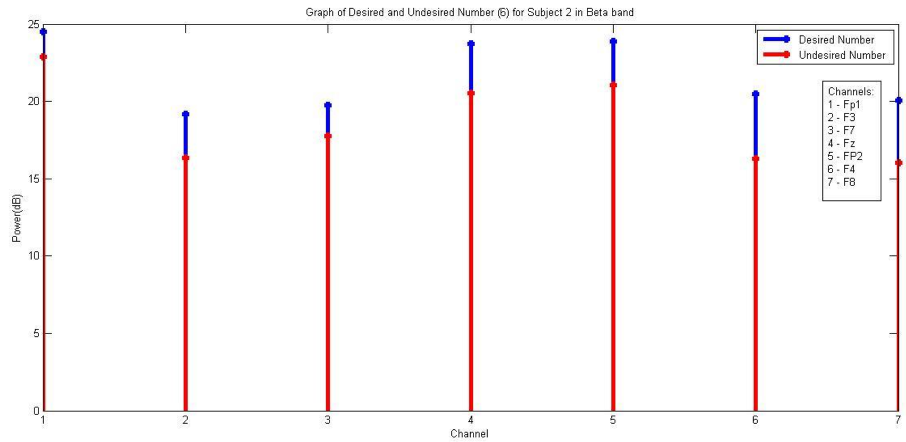

Figure 29 Graph of desired and undesired for the seventh trial in Beta band for Subject 2

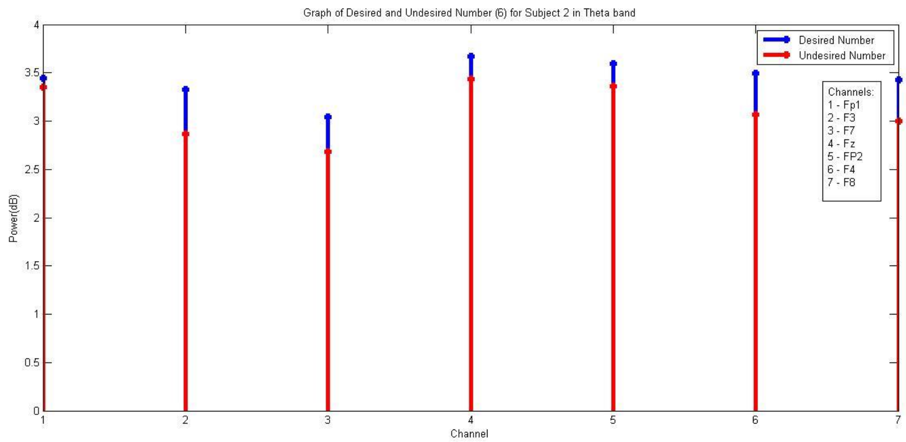

Figure 30 Graph of desired and undesired for the seventh trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the seventh trial.

Table 8: Average power for the seventh trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.144513	1.325156	1.452358	1.933158	2.010239	1.405918	1.483836
Dalpha	2.144615	1.428003	1.431125	2.029376	2.121698	1.637238	1.629301
Unbeta	22.87508	16.3222	17.73056	20.54963	21.07701	16.28323	16.05218
Dbeta	24.4984	19.19221	19.75801	23.73656	23.85036	20.46803	20.0679
Untheta	3.353368	2.889321	2.379568	3.496074	3.662133	3.089394	2.976188
Dtheta	3.443151	3.323799	3.041140	3.688664	3.59347	3.498064	3.428608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has still had the same significant value is at channel 5 which is at FP2. Based on the graph shown above for the seventh trial, it is still showing same good significant changes that correspond to desired and undesired graph in each band.

The 8th trial graph in each band representation with the same subject is shown below.

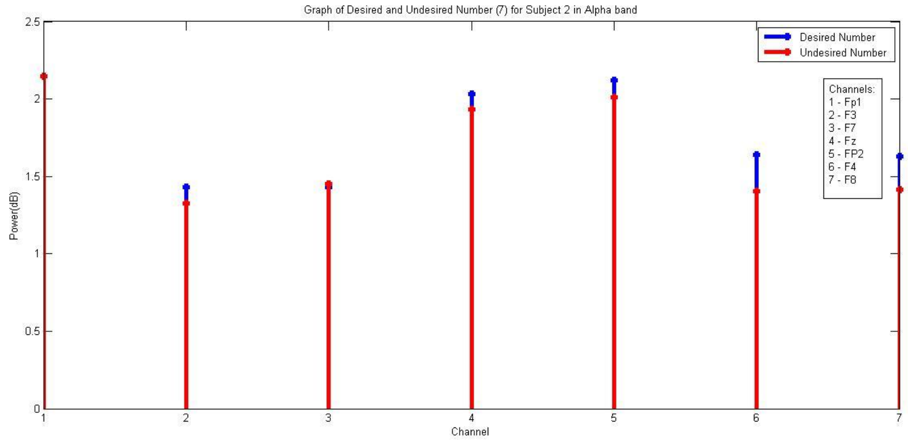

Figure 31 Graph of desired and undesired for the eighth trial in Alpha band for Subject 2

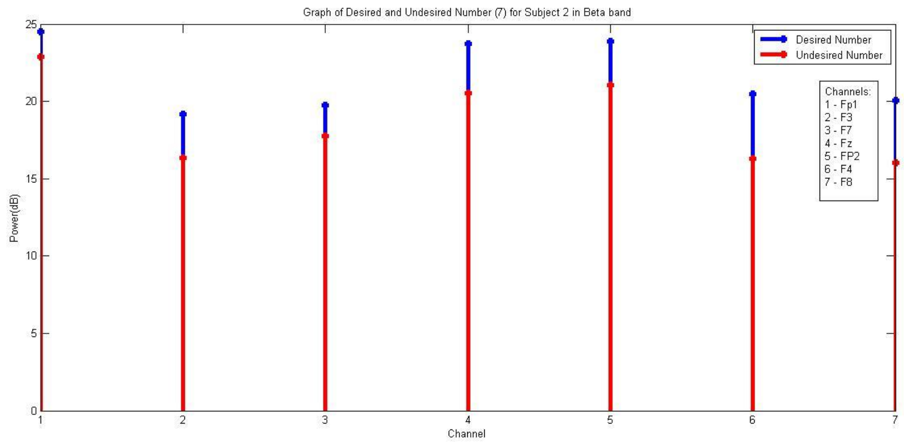

Figure 32 Graph of desired and undesired for the eighth trial in Beta band for Subject 2

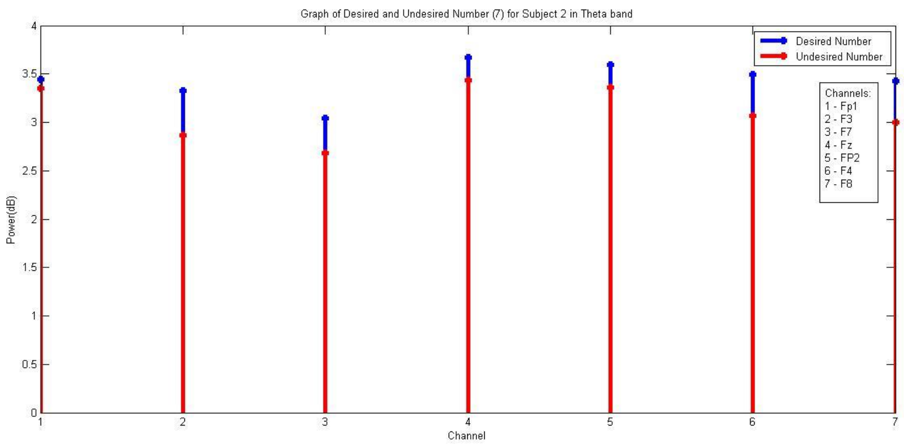

Figure 33 Graph of desired and undesired for the eighth trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the eighth trial.

Table 9: Average power for the eighth trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.149513196	1.325156	1.455358	1.973158	2.210239	1.485918	1.433836
Dalpha	2.154614654	1.328003	1.411125	2.028386	2.931698	1.621238	1.786301
Unbeta	22.99808087	16.7722	17.54056	20.55963	21.17701	16.28323	16.05218
Dbeta	24.49340017	19.17221	19.75801	23.73556	23.85026	20.46833	20.0689
Untheta	3.352368112	2.869321	2.679568	3.436074	3.362133	3.069394	2.996188
Dtheta	3.43225071	3.344299	3.012146	3.698664	3.98307	3.225064	3.345608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has still had the same significant value is at channel 5 which is at FP2. Based on the graph shown above for the eighth trial, it is still showing same good significant changes that correspond to desired and undesired graph in each band.

The 9th trial graph in each band representation with the same subject is shown below

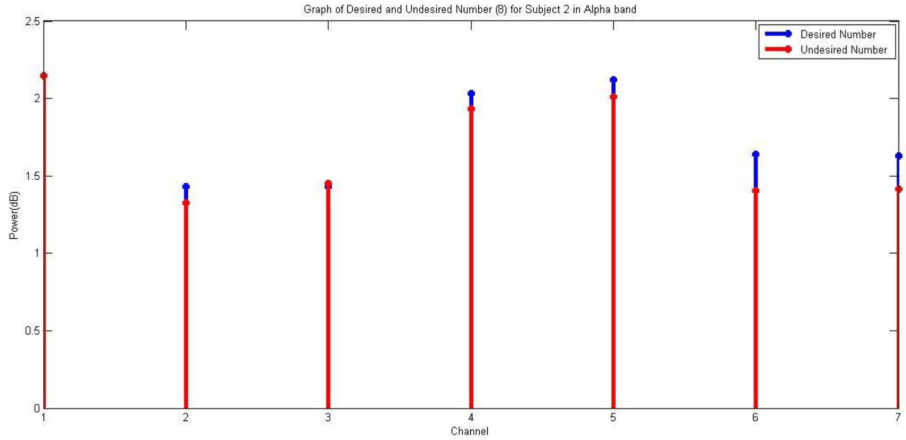

Figure 34 Graph of desired and undesired for ninth trial in Alpha band for Subject 2

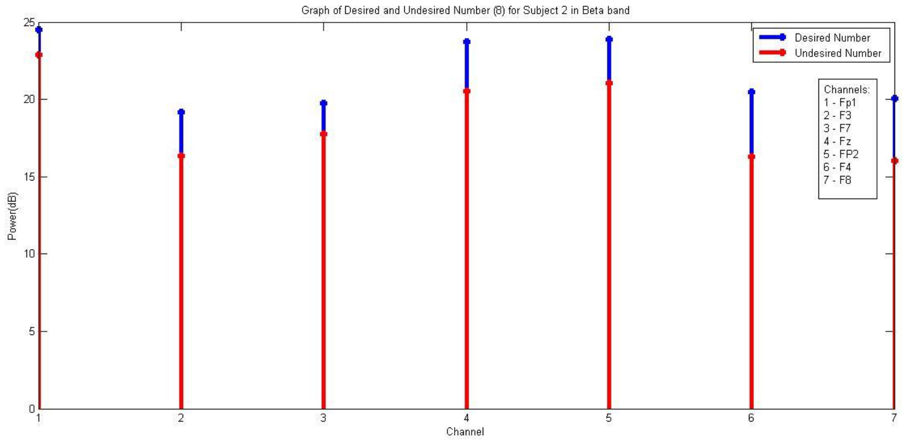

Figure 35 Graph of desired and undesired for ninth trial in Beta band for Subject 2

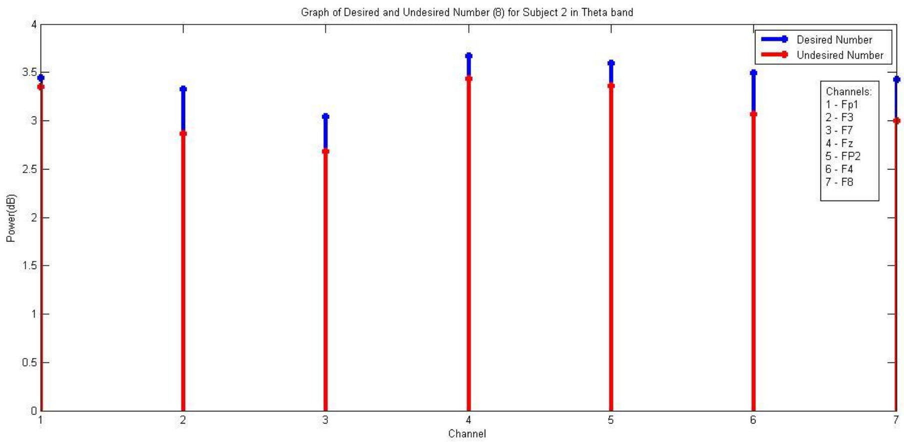

Figure 36 Graph of desired and undesired for ninth trial in Theta band for Subject 2

The table below shows the average power calculated in each band for ninth trial

Table 10: Average power for ninth trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.142513196	1.325156	1.455358	1.993158	2.210239	1.435918	1.483836
Dalpha	2.156614654	1.388003	1.481125	2.022386	2.931698	1.661238	1.986301
Unbeta	22.95808087	16.8722	17.84056	20.95963	21.37701	16.28323	16.95218
Dbeta	24.47340017	19.27221	19.77801	23.83556	23.95026	20.47833	20.8689
Untheta	3.452368112	2.969321	2.659568	3.236074	3.372133	3.019394	2.966188
Dtheta	3.63225071	3.644299	3.052146	3.698664	3.96307	3.255064	3.346608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has still had the same significant value is at channel 5 which is at FP2. Based on the graph shown above for the ninth trial, it is still showing good constant changes that correspond to desired and undesired graph in each band.

The 10th trial graph in each band representation with the same subject is shown below.

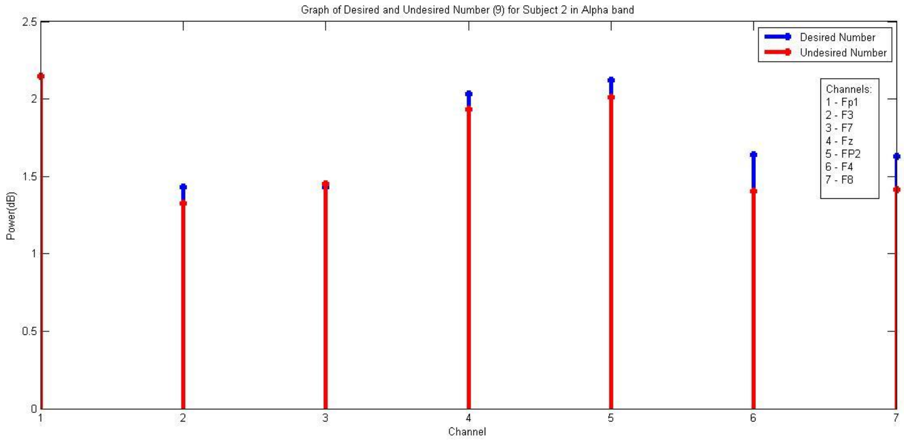

Figure 37 Graph of desired and undesired for the tenth trial in Alpha band for Subject 2

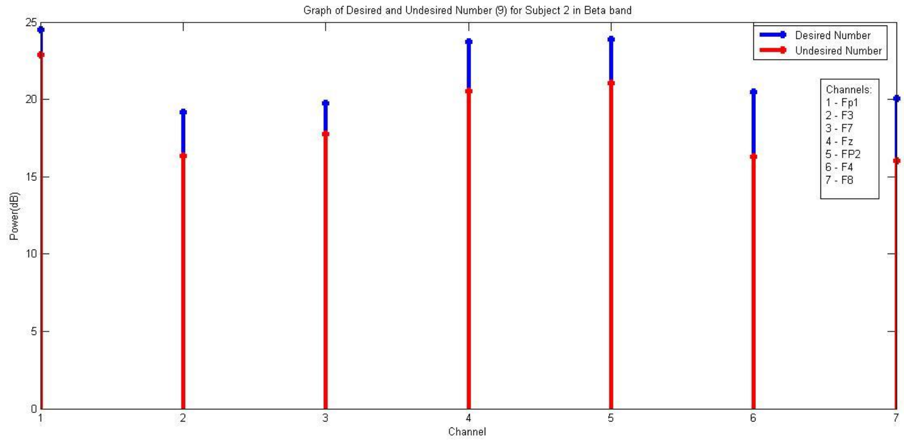

Figure 38 Graph of desired and undesired for the tenth trial in Beta band for Subject 2

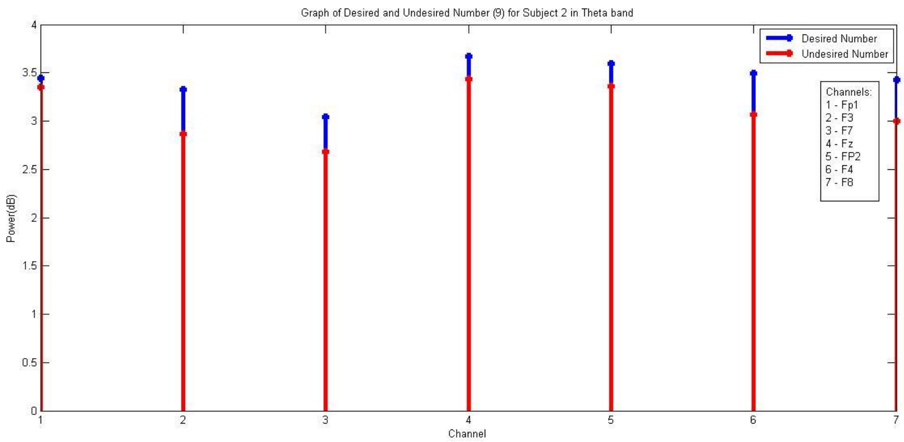

Figure 39 Graph of desired and undesired for the tenth trial in Theta band for Subject 2

The table below shows the average power calculated in each band for the tenth trial

Table 10: Average power for the tenth trial in each band for Subject 2

Band/ Channel	Fp1	F3	F7	Fz	FP2	F4	F8
Unalpha	2.142513196	1.335156	1.465358	1.943158	2.210239	1.435918	1.483836
Dalpha	2.149614654	1.488003	1.491125	2.072386	2.931698	1.661238	1.986301
Unbeta	22.92228087	16.2722	17.83056	20.95963	21.37701	16.28323	16.95218
Dbeta	24.44540017	19.23421	19.44801	23.83556	23.95026	20.47833	20.8689
Untheta	3.452368112	2.959321	2.759568	3.256074	3.392133	3.022394	2.987188
Dtheta	3.63225071	3.844299	3.045146	3.598664	3.98807	3.265064	3.446608

Based on the table shown and graphs, there are significant changes in desired and undesired graph in each band that can be concluded. The electrode/channel that has still had the same significant value is at channel 5 which is at FP2. Based on the graph shown above for the tenth trial, it is still showing good constant changes that correspond to desired and undesired graph in each band.

Each subject has undergone ten trials and each trial being displayed randomly. All graphs shown above are for one of the subjects that show good significant changes between desired and undesired number. However, there are few of them did not show good changes between desired and undesired number. There is few contributing factor that may lead to this and one of it relate to focusing and memory during the experiment. EEG basically captures all the brain activity and convert this into power spectrum [16]. This power change reflects the number of neurons synchronously being discharged. This is to show that the power changes related to cognitive and memory performance [16]. Due to this, when the subject is not able to memories well, it will reflect on the power spectrum of EEG. Hence, to overcome this situation, ones need to train more on the memorizing and focusing for the experiment.

All these graphs are represented by three power band which are an Alpha band (8-13Hz), a Beta band (12-38Hz) and Theta band (4-7Hz). To understand the EEG oscillation patterns have been observed to correlate with this experimental. In recent memory conducted by [17], the oscillation of Theta wave (4-7Hz) related with memory recognition by illustrating oscillatory pattern at different electrodes that simultaneously correlated with different task [18]. This band oscillation increased proportionally on how well the subject memorized and this band occurred in prefrontal cortex correlated with decision-making [18]. As for Alpha wave (8-13Hz), also related to memory recognition but it also observed with the increment of memory load in simple memory task but decrement as memory load increased during more demanding task [18]. Hence, this could explain the reason why some of the subjects did not perform well during the experiment conducted.

CHAPTER 5

CONCLUSION

A literature review has been conducted to provide a platform of understanding on the brain-machine interfacing, brain anatomy, stimulating and recording the brain, EEG signals, processing and analyzing EEG signals which provide a solid fundamental to support project continuation. The project has been implemented using BrainMaster with the aid of Matlab as the main software. The result is based on the desired number generated by the screen of computers which detected by EEG cap attach to the scalp of the subject. The desired number is displayed as the increment of amplitude (power) signals generated by EEG. Hence, the objectives of this study can be achieved which is to develop an EEG – based phone dialling system for locked-in people and to validate the developed system with a sufficient number of subjects.

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