EEG SIGNAL ANALYSIS FOR HUMAN EMOTIONAL INTELLIGENCE

by

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Dissertation submitted in partial fulfilment of

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CERTIFICATE OF APPROVAL

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Approved by,

____

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CERTIFICATE 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 acknowledgement, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

JEREMY LOH GUO XIANG

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ABSTRACT

Emotional intelligence plays an important role in human daily life. To date, most evaluation for emotional intelligences are being assessed through pen and paper based psychometric assessment and facial recognitions. These are subjective as the assessment performed are based on feelings or opinions of the participants to identify their level of emotional intelligence. This leads to the need of assessing emotional intelligence, brainwaves, and the correlation between them for objective based assessment.

In this project, the aim is to investigate the correlation between emotional intelligence and human brainwaves. The integration between an Arduino and Mindflex headset is carried out to measure one's brainwaves in respect to emotional intelligence. The system is utilized to observe and analyse patterns of emotional state of the participants while undertaking emotional Stroop test which is a test for the participants. They will be categorized into three groups which is average, higher than average and lower than average emotional intelligence. Subjects with higher level of emotional intelligence tend to have higher brainwave activity in the alpha and beta region. Brain activity increases with emotional intelligence.

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INTRODUCTION

1.1 Background Study

General intelligence of a person illustrated one's overall standing of intellectual attainment and capability, which can be seen as a tool to forecast one's occupational and academic achievement. In spite of the fact that one's overall intellectual functioning being indicated by general intelligence, less can be known for specific intelligences encompass it. As a result, general intelligence has been classified into various forms by psychologists. It is further separated into more detailed intelligences that illustrated either specific capabilities or groups based capabilities. The illustrated specific capabilities seemed to be correlated with each other yet distinguishable from one another [1]. Based on the concept of emotional intelligence, a platform measuring one's capability to think stems from the unique emotional skills for inherent and fascinating suggestion of theirs whereby real life events are supposedly being contributed by these differences. Common measure of one's competency in psychological can be forecasted through the average emotional intelligence rating while also distinguishing one's own emotional intelligence which included realization, control and usage of emotions [2].

Emotional intelligence is defined as the capability to recognise and control one's own emotions and of others. It can be categorised into three abilities: the awareness of emotion involving the capability to identify one's own emotions and others' as well, the capability to utilize emotions and exercise them to tasks such as thinking and solving difficult situations, and lastly the potential to control emotions, involving of managing one's own emotions as well as inspiring or soothing others [3].

There are plenty of utilization of emotional intelligence in human daily life. Its importance can be seen through one's physical health, mental well-being, success, conflict resolution, and relationship, not to mention leadership as follows [3]:

1. **Physical health**: To maintain a healthy life and manage stress successfully, we have to be aware of our self-emotional condition state and the responses towards stress in our life.
2. **Mental well-being**: Our attitude and viewpoint towards life are affected by emotional intelligence. People with higher emotional intelligence will generally be more pleased and have a better positive attitude viewpoint towards life. Higher emotional intelligence thus reduces depression and anxiety together with mood swings.
3. **Success**: People with higher emotional intelligence tend to be higher inner motivators, thus reducing procrastination, boosting self-confidence and enhancing self-capability to achieve goals by keeping track on them.
4. **Conflict resolution**: It will be effortless to deal with conflicts or even as much as avoid them as people with higher emotional intelligence can observe emotions of others and look from their point of view. Due to their nature apprehension towards the essentials and passions of others, these people have better negotiation skills. If we know what others want, we can give it to them in an easier way.
5. **Relationship**: We can communicate in a more effective way through better comprehension and controlling over our own emotions. People with higher emotional intelligence can understand their partners or friends easier. To achieve more passionate and accomplishment in relationships, we must understand those we treasure of their desires, affections and reactions.
6. **Leadership**: A better leader usually has higher emotional intelligence. Leaders that acquire the capabilities of influencing others, as well as deepens their bonds with others in workplace usually have higher emotional intelligence. Those who can identify the requirements of their people, thus promoting better solutions that lead to better accomplishment and workplace contentment are effective leaders.

We can measure our emotional intelligence through various methods. Common measures taken to measure emotional intelligence include answering series of questionnaires that describe our self-being, otherwise known as psychometric assessment, and identify the facial expressions of others [4]. Figure 1 shows an example of a psychometric assessment. After answering the questions, the score will be generated to interpret what levels our emotional intelligence will be at. Different psychometric assessments have different marking scheme and criteria for emotional intelligence.

15 Statements to Answer		Not at All	Rarely	Sometimes	Often	Very Often
1	I can recognize my emotions as I experience them.					
2	I lose my temper when I feel frustrated.					
3	People have told me that I'm a good listener.					
4	I know how to calm myself down when I feel anxious or upset.					
5	I enjoy organizing groups.					
6	I find it hard to focus on something over the long term.					
7	I find it difficult to move on when I feel frustrated or unhappy.					
8	I know my strengths and weaknesses.					
9	I avoid conflict and negotiations					
10	I feel that I don't enjoy my work.					
11	I ask people for feedback on what I do well, and how I can improve.					
12	I set long-term goals, and review my progress regularly.					
13	I find it difficult to read other people's emotions.					
14	I struggle to build rapport with others.					
15	I use active listening skills when people speak to me.					

FIGURE 1: An example of psychometric assessment for emotional intelligence

However, to identify facial expressions, we will need to have a set of images of some people showing different kind of expressions. Different expressions will have different emotions being linked to them. Still, psychometric assessment will be better at evaluating one's emotional intelligence as it is about ourselves and not others. We know ourselves better than other people do.

1.2 Problem Statement

Emotional intelligence plays an important role in human daily life. To date, most evaluations for emotional intelligence are being assessed through psychometric assessment and facial recognitions. These are subjective based as the assessment are being evaluated through feelings or opinions of the participants to identify their level of emotional intelligence. This leads to the need of assessing emotional intelligence, brainwaves, and the correlation between them for objective based assessment.

1.3 Objectives

The objectives of this project are included as below:

- To study the correlation between brainwaves and emotional intelligence.
- To develop a brainwave's monitor to observe and analyse the patterns on emotional intelligence state while undertaking emotional Stroop test.

1.4 Scope of Study

The scope of this project is to determine how emotional intelligence affects the brainwaves of the human brain. Participants will undergo psychometric assessment which will be categorised into three groups:

- Average (normal) range emotional intelligence.
- Lower emotional intelligence.
- Higher emotional intelligence.

The correlation of emotional intelligence and brainwaves is based on evaluation as of the brainwaves. A hardware will be developed to observe and analyse the brainwaves when undergoing emotional Stroop test for the three groups respectively. For example, in the Stroop test, there is naming of coloured negative words task. Individual which are more towards the depression boundary will tend to name the words slower than usual people. Thus, the correlation between the brainwaves with different levels of emotional intelligence can be investigated.

Using electroencephalogram (EEG), the brain's electrical activity can be recorded and examined. Different readings can be obtained through the usage of EEG, for example delta, alpha and theta, beta, together with gamma waves which indicate different kind of state the brain will be in. The brainwaves of the participants will be observed and assessed when they undergo the emotional Stroop test.

With the help of EEG and Arduino, the integration between them will be carried out which will then be used to measure one's brainwaves in respect to emotional intelligence. The integration between these will result in a small portable device which can measure brain's activity without much problem.

CHAPTER 2
LITERATURE REVIEW

2.1 Emotional intelligence measurement

A few of researchers have classified emotional intelligence as a capability, which can be evaluated most suitability through experimental of capabilities incorporating the subconscious handling of emotional statistics. Emotional intelligence can also be accessed through another means by self-evaluating surveys as it can be considered as a dispositional susceptibility. The matter of the possibility of one's self-assessment regarding their emotional skills raised concerns as attribute method to emotional intelligence measurement. The importance of emotional task performance is crucial as to study the relationship of emotional intelligence attribute to the task due to the fact that less administrations are required for questionnaires based emotional intelligence measurement, thus promoting its usage [2]. However, the truth is that there are some measurements of emotional intelligence trait produced within a concise hypothetical platform [5].

2.1.1 Electroencephalogram (EEG) on emotional intelligence

Doctors as well as researchers can observe the activities and problem inside the human brain through brain imaging techniques without the need of invasive neurosurgery. These techniques include functional magnetic resonance imaging (fMRI), computed tomography (CT), positron emission tomography (PET), electroencephalogram (EEG), magnetoencephalography (MEG) and near infrared spectroscopy (NIRS). However, in this project, EEG will be utilized instead of the others due to its ability in spotting changes within a millisecond timeframe. EEG directly records the electrical activity of the brain, while other methods measure changes through blood flow [6]. The images shown in Figure 2 and Figure 3 are some of the mentioned brain imaging modalities.

FIGURE 2: A computed tomography (CT) machine

FIGURE 3: An EEG machine

Number of neurons which are released at the same time is shown by the power of electroencephalogram (EEG) in a cognitive way. The volume or execution of cortical information action can be presumed to be calculated and shown by the power of EEG since the cortical layer is highly associated with intelligence by its size and depth [7]. When neurons are active, current will be flowing through, thus the waves where electric current passes though from one neuron to another is known as brainwaves [8].

When the activity of these neurons occurs, current flows locally produced [8]. In this activity, jointly driven by an electric current flow from one neuron to neuron to another and it will produce wave patterns (waves) and is known as the wave of the brain (brainwaves).

However, unknown factors played important roles which can have an impact towards the power measurements. For examples, the skull's diameter can influence the performance of the EEG, the cerebrospinal fluid's capacity also greatly influenced the outcome, and others such as the types of task performance, age and genders of the individual.

Though the usage of electroencephalogram EEG, the average intelligence between different genders produced different results for brain resting action. The variable used here to investigate is three discrete narrow frequency range of alpha, α [9]. The upper-alpha range (10.5 – 12.5 Hz) is closely associated to general intelligence and emotional intelligence, which is related to semantic memory activities [7]. Less desynchronization has been shown by individuals with high emotional intelligence in the region of the upper-alpha range [10].

A person who has better corresponding left-sided frontal initialization is resulted with the present of higher attribute in emotional intelligence [11]. People who are more out-going and love to socialise produced better corresponding left-sided frontal initialization [12]. People who appeared to be more confident and socialise on their own accord are those who have better left-frontal activation as to those who are shy [13]. Various researches showed that self-control have parallel connections between left-sided asymmetry together with their emotion control capabilities being strengthened [14]. Therefore, greater attribute in emotional intelligence which existed in some individuals proved to focus on searching solutions for problems than managing them [15].

A higher corresponding of right-frontal initialization is actually harmful as it is identified to have relationship with a psychological related emotional sickness whereby it is unpleasant to pinpoint and explain feelings [11]. In the upper-alpha range, which has a frequency range of 10.4Hz to 12.4Hz, individuals with high emotional intelligence will show less desynchronization and lesser theta desynchronization in the left hemispheric compared to individuals with average emotional intelligence [10]. It can be seen that there are considerably more stimulation in the left-frontal for individuals that have higher emotional intelligence [11].

2.2 Types of brainwaves

The brainwaves of human are divided into five different types [16]:

- Delta.
- Theta.
- Alpha.
- Beta.
- Gamma.

Delta waves which have a frequency of around 0.5Hz to 3Hz, fundamentally take place when one is in a dream-free sleep. It is known to be our deepest state of mind. Theta waves with a frequency of 3Hz to 8Hz happens during one's sleeping time too. However, during the Zen meditation, it appears to have theta waves as well. Daydreaming or assuming meditation under a conscious mind will result with alpha waves, with a frequency range of 8Hz to 12Hz. Aerobic exercises may also induce alpha waves. Beta waves with a frequency of 12Hz to 30Hz, can be observed during the performing of cognitive tasks or any other tasks. It happens when one is alert or attentive towards something, such as engaging in problem solving activities or decision making. The fattest bandwidths for brainwaves will be the gamma waves, which has an enormous range from 25Hz to 100Hz. This happens when the brain is processing information continuously from different cerebral areas which also induce greater conscious perception [16, 17].

2.3 EEG Mindflex Headband

NeuroSky developed the Mindflex using the technology of ThinkGear as the fundamental. The Mindflex is known as a device to train the brain. It contains the EEG headset which is functioning wirelessly. The EEG headset is shown in Figure 4.

FIGURE 4: EEG Mindflex headband

The headband can be powered up by three AAA batteries of 1.5V. Brain signals are picked up the metal electrode confined to the forehead by monopolar method. The null reference will be clipped onto the earlobes as it should be placed somewhere not influenced by the activity of the brain. The concentration value and/or attention value can also be determined through the signal processing unit. Using a wireless network, the headband will broadcast the analysed signals to the controlled unit.

2.4 Critical Review

2.4.1 Advantages of EEG

- During the process of utilizing EEG, zero electrical current will pass through the body.
- EEG provides a better complete picture of brain activity compared to other brain imaging techniques. It provides what is going on in the brain – the brain cells' activity, rather than the brain structure.
- EEG does not cause pain to the user when in use.
- High precision in time measurements as of any other electrical recording system. Electrical activity of the brain changes swiftly thus requires high time resolution to accurately find out which electrical moments happen at the exact moment.
- Unlike other devices that need to insert electrodes into the brain, electrodes of EEG are simply attached to the scalp only.
- Simple and economical. Relatively easy to operate and does not produce any complications.
- Capable at distinguish different levels of sleep, and also the effects of medication or drugs that are being consumed.
- EEG does not expose the participants or patients to magnetic fields of high intensity.

2.4.2 Limitations of EEG

- EEG has poor spatial resolutions. This results in difficulty to pinpoint the exact spot where electrical activity of the brain originates from.

2.4.3 Proposed Improvement

- Improve the spatial resolutions to allow the exact location of the brain electrical activity to be pinpointed out.

2.4.4 Application of EEG

1. *Human factors*

   EEG is utilized to determine an individual's characteristics and personality traits such as introversion or extroversion.
2. *Social interaction*

   To learn more about leaderships as well as interactions, EEG is utilized to study the processes of the brain to find out the conversations and actions synchronization.
3. *Psychology and neuroscience*

   Usually, EEG is used to learn the brain processes that include memory, attention and memory.
4. *Clinical and psychiatric studies*

   For a better understanding of the human brain, without needing to insert any electrodes into the brain, EEG helps in evaluating the patients' state of mind, determine the problems within the brain and classify any symptoms that can't be diagnosed easily.

CHAPTER 3
METHODOLOGY

Step 1: Variety of brainwaves that will be monitored.

There are altogether four types of brainwaves that can be obtained through the usage of EEG. In this case, the Mindflex EEG Headband is being used to measure these brainwaves.

- Theta (3 – 8Hz)
- Alpha (8 – 12Hz)
- Beta (12 – 30Hz)
- Gamma (25 – 100Hz)

The theta waves can be observed in sleep and during deep meditation. The alpha waves can be observed when the brain is in resting state. The beta waves can be observed in an alert and attentive state, or during problem solving sessions and making decision. It can also be observed when one is focused in mental activities. The gamma waves which are the fastest brain waves can be observed when one's brain is processing information continuously from different areas of the brain.

Step 2: Preparations of the components.

The necessary components are being prepared in this step. The parts listed below are some of the required components:

- Arduino Uno
- Breadboard
- Mindflex EEG Headband
- Batteries

The tools required are as follows:

- Soldering iron
- Screwdriver
- Wire cutter

Step 3: Interfacing the Mindflex EEG headband with the Arduino.

1. At the back cover of the headband, remove four screws of the left pod. Figure 5 below shows a Mindflex EEG headband.

FIGURE 5: Mindflex Headband

2. Identify the position of NeuroSky board and look for the pins labelled T and R. these pins are used by the EEG board to connect to main circuit board of the microcontroller.
3. Solder a length of wire to the “T” pin and avoid short circuiting the nearby pins.
4. Solder another wire length to ground whereby the ground connection of the battery is situated.
5. To allow the two wires to go through the case, drill a hole at the case.
6. After drilling the hole, allow the wires to pass through, then put back the case and secure back the screws.
7. Lastly, connect the T pin wire of the Mindflex headband to Arduino RX pin and the other wire to Arduino GND pin.

Step 4: Code the program required to test out the different type of brainwaves.

Few individuals will be asked to volunteer and the brain waves pattern will be recorded in digitized signal. The participants will be undergoing the emotional Stroop test and the readings of the brainwaves will be recorded down.

During self-assessment, the participants will be wearing the headband too to study on how their brain works for different types of questions being answered.

Through the Processing software in Figure 6, the software will be used graphs the brain activity of the participants over time. The sketch (program code) is designed to coordinate with the Arduino sketch.

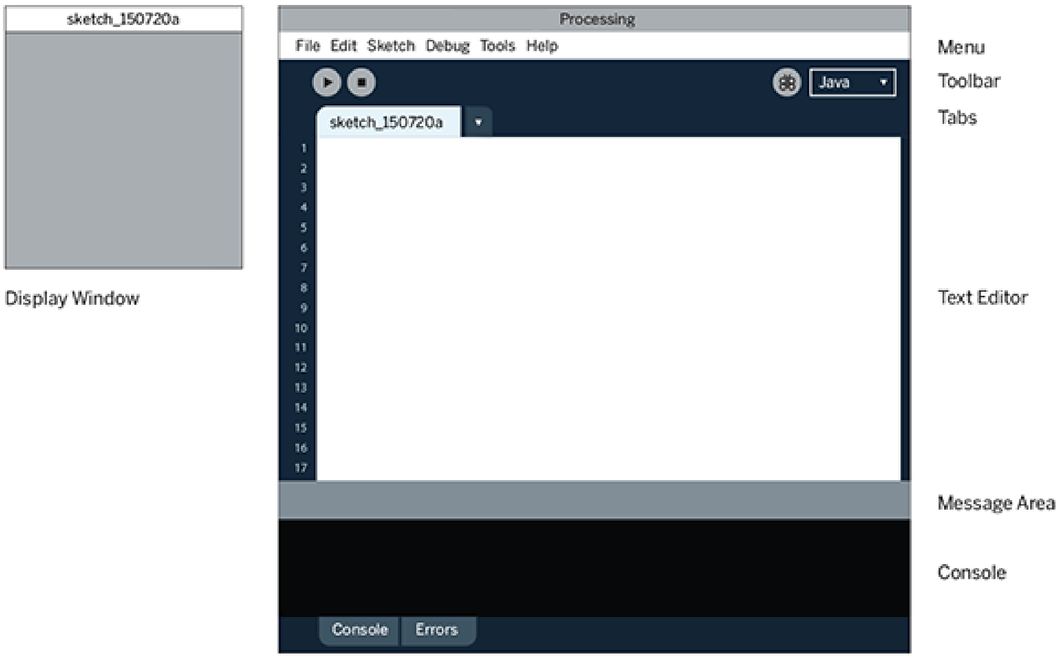


FIGURE 6: Processing sketch which will be programmed to graph the brain activity of the participants

Step 5: Participants undergo emotional Stroop test while hooked onto the Mindflex.

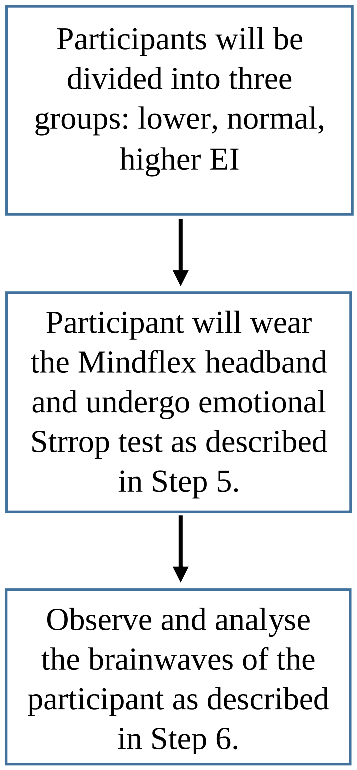
Emotional Stroop test can be utilised as an approach to assess emotions. This test is designed to test the response time of the participants when naming the colours of negative emotional words. The participants are required to name the emotional words, for example, “cancer”, “war”, “lonely”, “regretful”, and the neutral words as well, for example, “clock”, “car”, “laptop”, separately.

Raw data will be collected through the Arduino serial monitor whereas the Processing software will then graph the brain activity of the participants.

Step 6: Observe and analyse brainwave patterns of the participants.

The brainwave patterns of the participants undergoing emotional Stroop test will be observed and analysed according to the result obtained through the Processing software. The data such as alpha, beta and gamma waves will be analysed to determine the correlation between emotional intelligence and brainwaves.

Flowchart on the procedure of EEG analysis on Human Emotional Intelligence



CHAPTER 4
SCHEDULE

4.1 Gantt Chart

The schedule below shows the estimated timeline for the project in Final Year Project 1 (FYP1).

TABLE 1: FYP1 schedule

Details	**Week (FYP 1)**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Topic Selection														
Preliminary Research Work														
Research on the materials needed to carry out the project														
Extended Proposal Submission														
Purchase Mindflex														
Research on the brain library for Arduino														
Arrival of Mindflex														
Project Work carries on: - Integrate Arduino with Mindflex headband - Download Brain library and install to Arduino - Set up the TFT colour display to display results														
Proposal Defence														
Project Work carries on: - Using Arduino sketch to program the code for software part														
Draft Interim Report														
Interim Report														

The schedule below shows the estimated timeline for the project in Final Year Project 2 (FYP2).

TABLE 2: FYP2 schedule

Details	**Week (FYP 2)**													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Work carries on: - Integrate Arduino with Mindflex headband - Download Brain library and install to Arduino - Set up the TFT colour display to display results														
Project Work carries on: - Using C/C++ to code the necessary programs to obtain brainwaves result - Study how the daily tasks affects brain waves pattern														
Study the brainwaves obtained from the Arduino sketch														
Update and debug the program (if any)														

Process
Milestone

4.2 Project Key Milestones

FYP1 key milestones:

Week 1 - 2

- Selection of project title.
- Confirmation of project title.

Week 3 - 5

- Preliminary research work.
- Conduct literature review on emotional intelligence, Stroop test, different type of brain waves.
- Alpha brain wave is highly associated with the frontal part region of the brain.

Week 6 - 8

- Hardware and tools needed to carry out the project.
- Research on which software is best to analyse the raw data from Mindflex.
- Processing and Arduino can complement each other when integrated with Mindflex.

Week 9 - 12

- Research on the Processing software
- How does Processing complement with Arduino.
- Deeper learning on the Arduino brain library.
- Deeper understanding towards the Mind Flex headset and how it functions after integration with Arduino.

FYP2 key milestones:

Week 1 - 4

- Research on the coding to obtain signal values.
- Solder Mindflex headband's T pin and connect to Arduino's RX pin.
- Solder Mindflex headband's ground pin and connect to Arduino's ground pin.

Week 5 - 8

- Obtain the emotional intelligence of volunteered participants through psychometric tests.
- Conduct emotional Stroop tests on participants while engaging in Mindflex headband.
- Observe and analyse collected data
- Make sense on the signal values obtained from Mindflex headband.

Week 8 - 10

- Research and conduct EMG on participants.
- Relate muscle movements to emotional intelligence.

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Results and Discussion

Hardware

Figure 7 provides the Mindflex hardware's basic layout. Most actions are situated in the headband of the Mindflex, which has the EEG hardware within it. The microcontroller within the headband will compute data through the EEG chip and produces feedbacks wirelessly to a base station, where the fan will levitate the ball along with the illumination of several LEDs to represent the current attention level of the user.

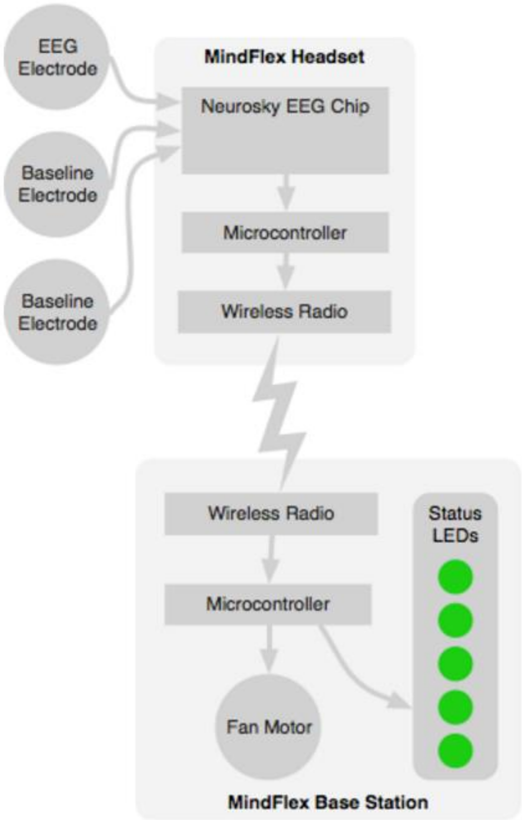


FIGURE 7: Data extraction of Mindflex – basic layout

From Figure 7, it also shows that few methods can be utilized for data extraction for the Mindflex. The easiest and fastest is through the LEDs on the base station to find out the attention level of the user. However, this method is not as accurate as possible it can get. Thus, to obtain a better result, the Arduino is used to be integrated with the Mindflex headband, which will allow direct acquisition of serial data through the Neurosky EEG chip.

The schematic shown in Figure 8 is on how the integration between Mindflex headband and Arduino works.

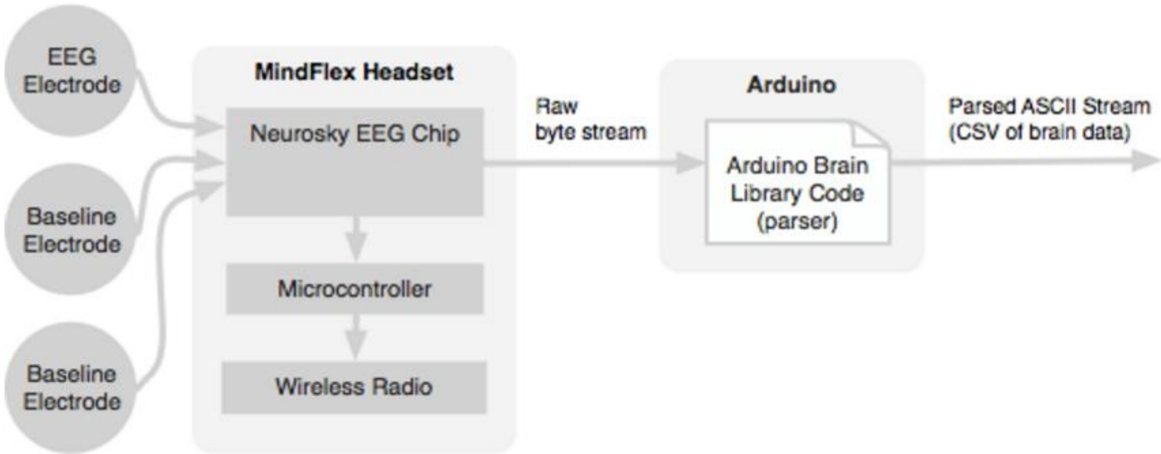


FIGURE 8: Schematic of integration between Arduino and Mindflex headband

T pin within the Neurosky Board of Mindflex

On the EEG board, there are these T and R pins on the EEG board whereby they are used to communicate serially to the microcontroller of the main board. These pins will be utilized to obtain the brain data. The T pin is soldered to a length of wire, with any thickness is acceptable. However, as mentioned before, this step must be tread carefully as to avoid the neighbouring circuit getting short circuited. The T pin will be connected to the Arduino's RX pin.

Common ground within Neurosky Board of Mindflex

Solder another wire to any of the grounding point on the EEG board. This will then be connected to the ground pin of the Arduino. Figure 9 shows the T pin of the Mindflex soldered to a wire which will then connect to the Arduino's RX port.

FIGURE 9: T pin soldered which will then be connected to the Arduino's RX port

Software

Data obtained from the Neurosky is complex as it involves a stream of raw bytes that are needed to be analysed before knowing what they meant. However, an Arduino library has been written and can be obtained at GitHub. The brain library functions to compute data from Neurosky-based EEG headband. The design of this library is to simplify the raw data from Neurosky chip into an understandable ACSII string of comma-separated value, or to gain entry of the processed brainwaves information immediately from the Arduino sketch.

```
fyp_brain

#include <Brain.h>

Brain brain(Serial);

void setup() {
    Serial.begin(9600);
}

void loop() {
    if (brain.update()) {
        Serial.println(brain.readCSV());
    }
}
```

FIGURE 10: Program code to obtain brain signals

Figure 10 shows the program code that will obtain the raw data values for the brainwaves as explained below. The above program in Figure 10 will produce the values as in Figure 11:

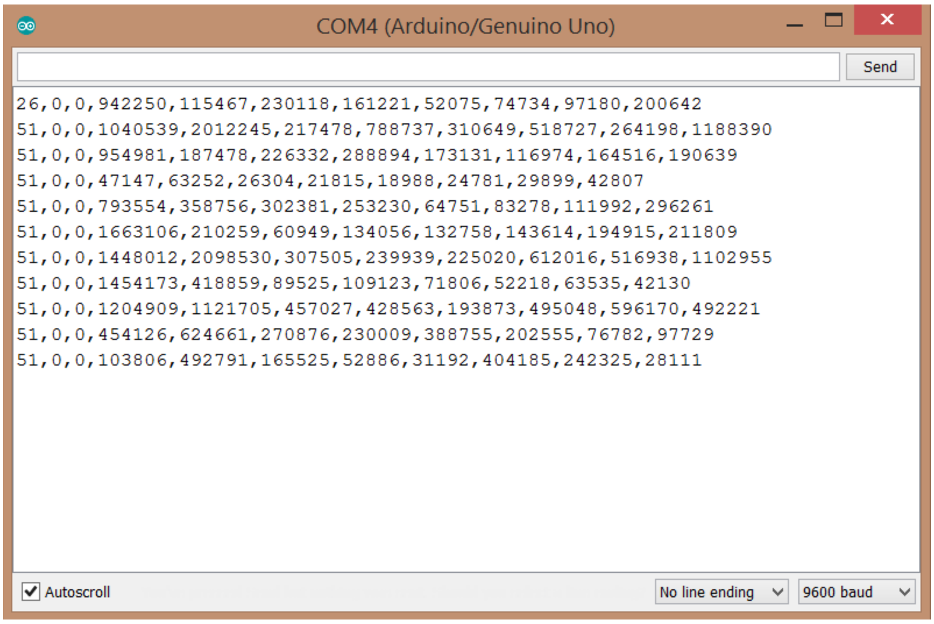


FIGURE 11: Signal values shown after participant wore the integrated Mindflex headband

From Figure 11, the values obtained from the Mindflex headband when the participant is engaged with it are broken down respectively. From left, the respective values are “signal strength”, “attention” and “meditation”, followed by “delta”, “theta”, “low alpha” and “high alpha”, and lastly “low beta”, “high beta” together with “low gamma” and “high gamma”.

The data obtained through this is believed to be heavily filtered whereby the values aren’t easily mapped to real-world units. The frequencies are as follows [16, 17]:

- Delta (1 to 3Hz): Sleep
- Theta (4 to 7Hz): relaxed, meditative
- Low Alpha (8 to 9Hz): eyes closed, relaxed
- High Alpha (10 to 12Hz)
- Low Beta (13 to 17Hz): alert, focused
- High Beta (18 to 30Hz)

- Low Gamma (31 to 40Hz): multi-sensory processing
- High Gamma (41 to 50Hz)

Other than the data mentioned above, there are also values of "attention" as well as "meditation" that are produced by the NeuroSky chip within the Mindflex headband. These two values are represented in Figure 11 at the second (attention) and third (meditation) values from the left.

- Attention:
  - ➢ Reflects the participant's mental state in focusing or being attention to something. The "attention" value might decrease if the participant is distracted or lack of focus.
- Meditation:
  - ➢ Reflects the participant's mental state of calmness and the ability to relax oneself. If the participant closed his or her eyes, it may increase the "meditation" value.

With the consent from one of the participant, Figure 12 shows when the participant is focusing on something (e.g: solving maths questions), whereas Figure 13 shows when the participant is closing his eyes and do nothing (meditating).

FIGURE 12: One of the participant focusing on calculation task

FIGURE 13: One of the participant meditating by closing his eyes and do nothing

Figure 14 and Figure 15 below show the values obtained when the participant is in attentive mode and meditative mode.

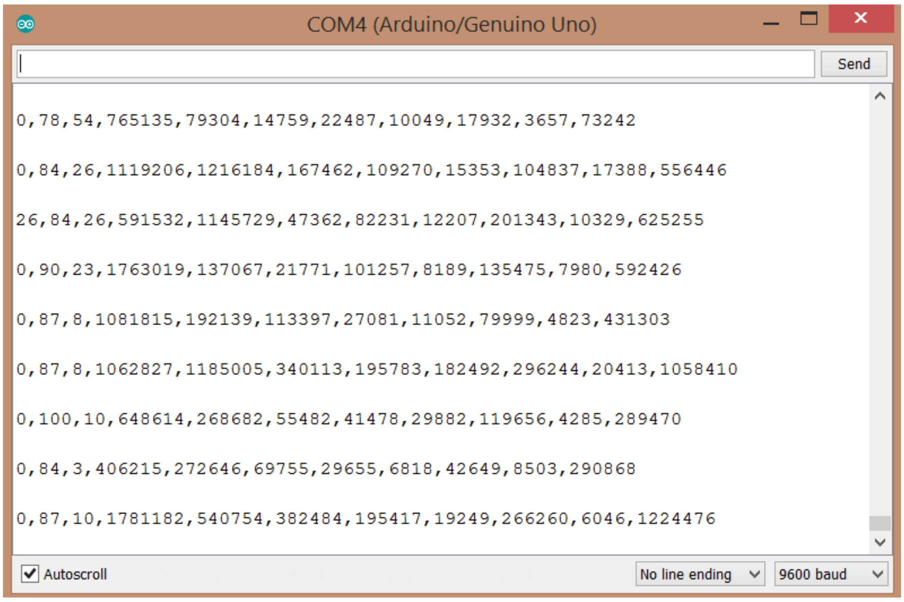


FIGURE 14: Values when the participant is solving maths problems

As per the results obtained as shown in Figure 14, the "attention" value, which is the second from left, is having the range of 75 to 100 when the subject is solving maths problems. This indicated that the participant is being attentive and focused on the tasks.

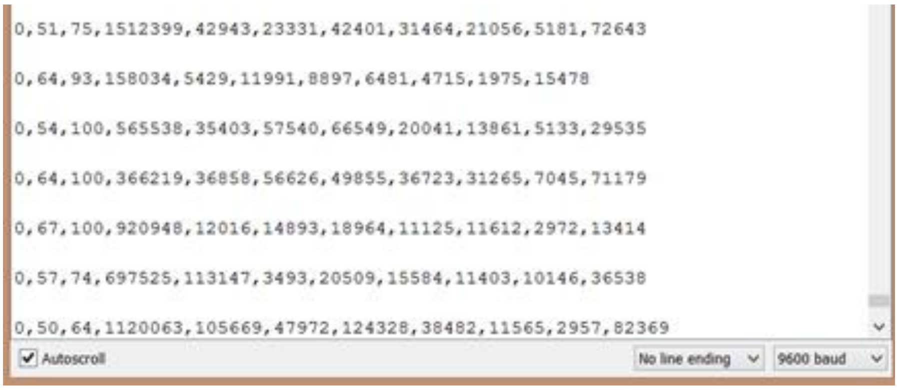


FIGURE 15: Values when the participant is closing his eyes and meditative mode

As per the results obtained as shown in Figure 15, the "meditation" value, which is the third from left, is having the range from approximately 75 to 100 as well when the participant is closing his eyes and doing nothing. This indicated that the participant is in meditative mode. The values from Figure 14 and Figure 15 are expected around once per second.

Eight participants volunteered for this project. All eight participants were categorised as average emotional intelligence. Through the software known as Processing, the changes in brainwaves over time are obtained. The function of Processing in this project is to read data obtained from the Mindflex EEG headset connected to the Arduino via USB port.

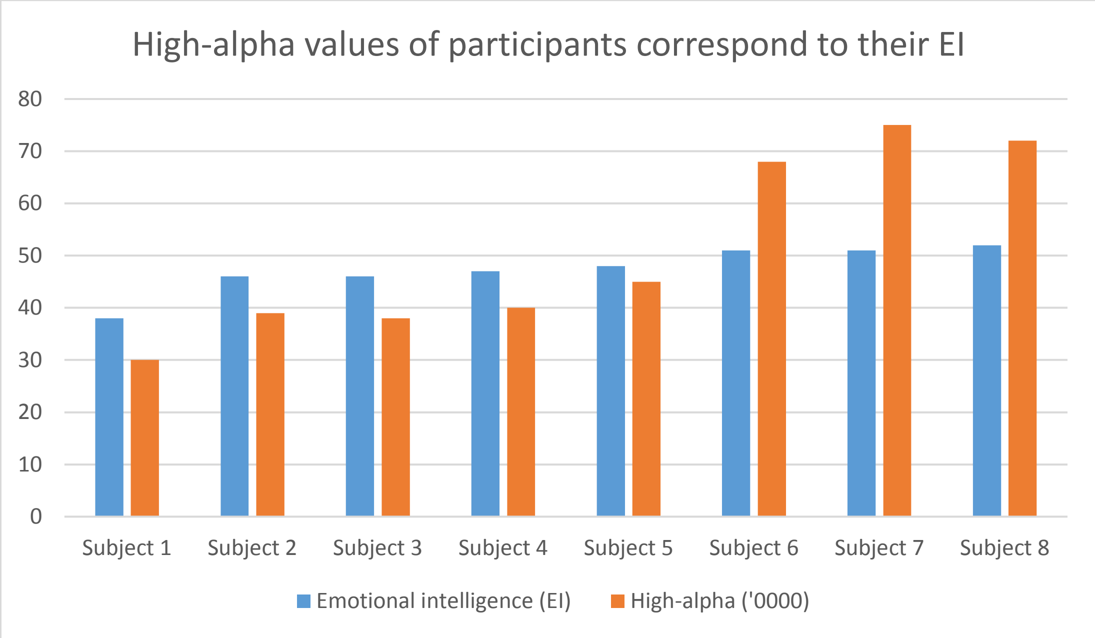


FIGURE 16: High-alpha value of participants correspond to their EI

Based on Figure 16, as the emotional intelligence (EI) of the participants (subject 1 to subject 8) increases, the high-alpha brainwave values increase as well. This indicates that brain activity increases with emotional intelligence. Therefore, people with higher emotional intelligence tend to be more creative and imaginative.

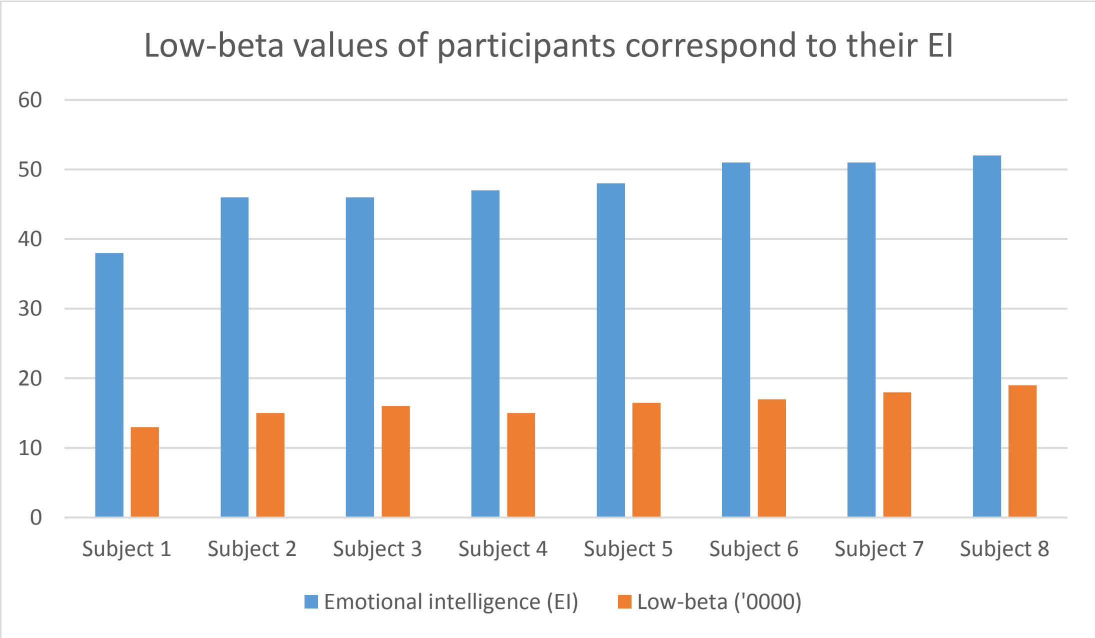


FIGURE 17: Low-beta value of participants correspond to their EI

Based on Figure 17, as the emotional intelligence (EI) of the participants (subject 1 to subject 8) increases, the low-beta brainwave values increase too. People with higher beta brainwaves are more capable of generating positive thoughts as compared to those with lower beta brainwaves. People with higher level of emotional intelligence shows more positive outlook on their life than those with lower level of emotional intelligence.

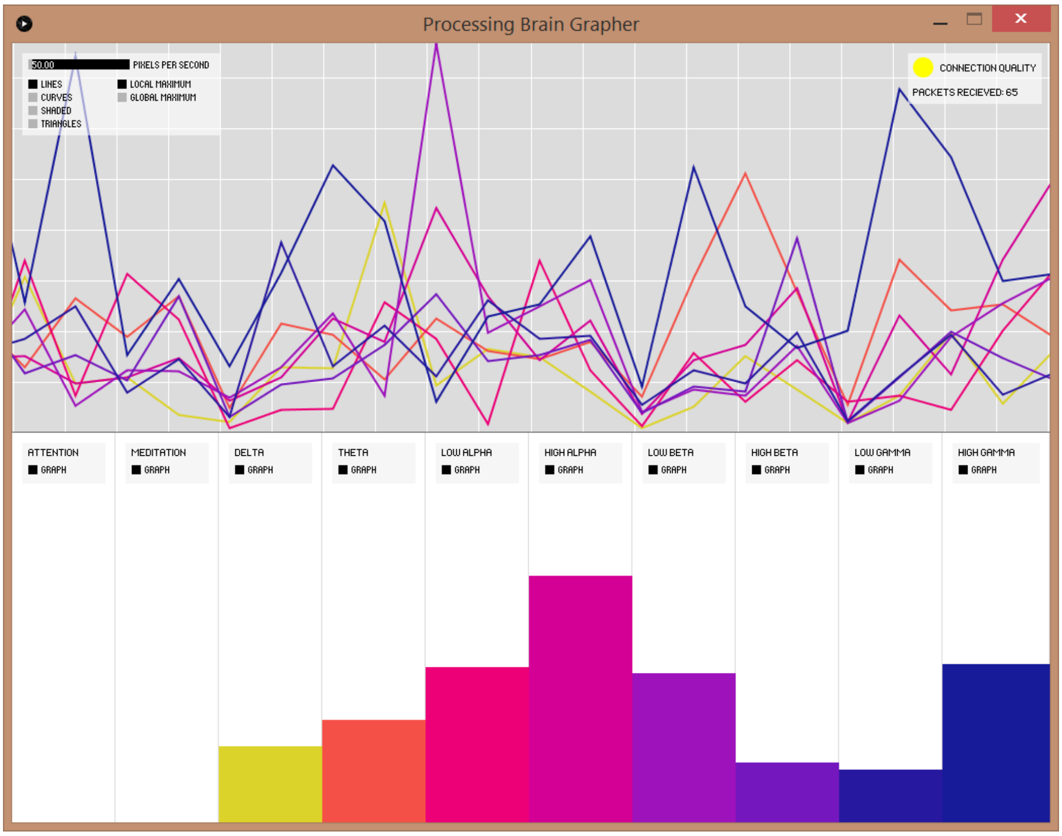


FIGURE 18: Changes in brainwaves of one participant over time during emotional Stroop test

Figure 18 shows the changes in brainwaves of one participant over time when undergoing emotional Stroop test. This is achieved through the Processing software which allowed a better visualization of the brainwaves compared to the raw data obtained in Figure 14 and Figure 15.

5.2 Problems Encountered

There are few problems encountered while capturing the reading of the values. Problems that are encountered such as:

- The length and amount of hair of the participants
- The cleanliness of the forehead and ears of the participants
- The connection between the Arduino board and laptop
- The wire connected from the Mindflex to the Arduino.
- Values for delta, theta, alpha, beta and gamma fluctuate at times which require more verification and research.

The participants are required to have short hair which doesn't obstruct the data recording process. Long hair will disturb the signal processing of the Mindflex which will results in signal strength not reaching to zero. If the signal strength doesn't reach zero, the values for "attention" and "mediation" remain at zero throughout the process. To avoid getting weak and unstable signals due to the oiliness of participants' face, they are required to have clean facial prior to the experiment. The connection between the Arduino and Mindflex headband have to be strong whereby Arduino board will be powered up by the laptop whereas the Mindflex headband will be powered by triple A batteries. Wires connection between the Mindflex headband's T pin and ground pin and the Arduino RX and ground pins must be ensured that they are connected successfully.

Chapter 6
Conclusions and Recommendations

This project is aimed to determine the correlation between human emotional intelligence and brainwaves. The values ‘attention’ and ‘meditation’ obtained from the Mindflex headband (NeuroSky chip) can be used to determine how emotional intelligence relates with brainwaves. Higher level of emotional intelligence will result in higher “attention” value while undergoing emotional Stroop tests. However, the brainwaves associate with the “attention” value is unknown. Higher “attention” value shows that one is more focused on the tasks given and lower ‘attention’ shows that one is distracted or lack of focus on the tasks given. When one is closing eyes and not engaging in any activity, the “meditation” values will increase.

Participants with higher level of emotional intelligence tend to have higher alpha and beta brainwaves activity. In another aspect, participants with higher level of emotional intelligence have a better positive outlook towards life. They also are more creative and innovative.

Participants engaging in Mindflex headband are required to have shorter hair and clean facial to avoid weak and unstable signal being processed. If ‘signal strength’ is not zero, the values for ‘attention’ and ‘meditation’ will remain zero.

6.1 Recommendations

The Mindflex can also be used to measure other human vitality signs such as heart beat and body temperature in relation to emotional intelligence or brainwaves. However, more research is needed to understand how can the Mindflex be integrated to suit this quest.

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