MENTAL FATIGUE STUDY USING ELECTROENCEPHALOGRAPH (EEG) IN LEARNING THE PHYSICS AT SENIOR HIGH SCHOOL'S STUDENTS

THESIS

Submitted to International Program Faculty of Industrial Technology
in Partial Fulfillment of the Requirements for the degree of Sarjana Teknik Industri

Name : Faradhina Azzahra
Student No. : 13 522 052

INTERNATIONAL PROGRAM
INDUSTRIAL ENGINEERING DEPARTMENT
FACULTY OF INDUSTRIAL TECHNOLOGY
UNIVERSITAS ISLAM INDONESIA
YOGYAKARTA
2018

AUTHENTICITY STATEMENT

In the name of Allah, I hereby certify that this research is based on my own work and studies, except for the citation and summaries in which of those is explicitly knowledge. If in the future this statement is proved not right and violated the legal regulation of papers and intellectual property rights, I agree Universitas Islam Indonesia to revoke my bachelor certificate.

Yogyakarta, April 20th, 2018

Faradhina Azzahra

THESIS APPROVAL OF SUPERVISOR

ELECTROENCEPHALOGRAPH (EEG) STUDY OF MENTAL FATIGUE IN LEARNING THE PHYSICS AT SENIOR HIGH SCHOOL'S STUDENTS

THESIS

By:

Name : **Faradhina Azzahra**

Student Number : **13 522 052**

Yogyakarta, February 11th, 2018

Supervisor

(Ir. Hartomo Soewardi, M.Sc., Ph.D.)

THESIS APPROVAL OF EXAMINATION COMMITTEE

MENTAL FATIGUE STUDY USING ELECTROENCEPHALOGRAPH (EEG) IN LEARNING THE PHYSICS AT SENIOR HIGH SCHOOL'S STUDENTS

By:

Name : Faradhina Azzahra

Student Number : 13 522 052

Had been defended in front of Examination Committee in Partial Fulfilment of the Requirement for the Degree of Sarjana Teknik Industri Faculty of Industrial Technology Universitas Islam Indonesia

Yogyakarta, April 20th, 2018

Examination Committee

Muhammad Ridwan Andi Purnomo, ST., M.Sc., Ph.D. __________
Examination Committee Chair

Ir. Hartomo, M.Sc., Ph.D. __________
Member I

Amarria Dila Sari, ST., M.Sc. __________
Member II

Acknowledged by,

Head of Department

International Program Industrial Engineering

Universitas Islam Indonesia

(Muhammad Ridwan Andi Purnomo, ST., M.Sc., Ph.D.)

DEDICATION PAGE

This thesis dedicated to,

My parent and my sisters

Mama and Papa for unconditional support both in physiology and financial

Mbak Dhini and Mbak Rintan as for best role model ever

My beloved class, IPIEUII 2013

Friends do not come any better than you all

Universitas Islam Indonesia

All lecturers, staffs, and colleagues who give chance and experience in developing both in hard and soft skill during study in university.

MOTTO

"Indeed, with hardship [will be] ease. So when you have finished [your duties], then stand up [for worship]. And to your Lord direct [your] longing."

(QS. Ash-Sharh: 6-8)

Meanwhile, wallpaper of my phone is written

"You can do it girl, of course you can. You will get there."

PREFACE

Assalamualaikum Wr. Wb.

Alhamdulillah and gratitude are presented to Allah, which has always grants with His grace, strength, and blessing so the author could complete this undergraduate thesis.

Therefore, the author would like to thank for those who have been constantly sending supports and motivations in the making of this report. The author would like to thank:

1. Allah SWT, for all uncountable blessings every day and also Rasulullah Muhammad SAW for His guidance in the right way.
2. My beloved mother, father, sisters, and other families for the prayer, support, and motivation.
3. Ir. Hartomo Soewardi, M.Sc., Ph.D. as the supervisor for unlimited time for helping, supporting, and advising.
4. Mr. Catur Atmaji, S.Si, M.Sc as outer supervisor for lending and teaching the operation of Ganglion tools.
5. Mrs. Tri Handayani as Physics teacher in Senior High School for her helpfulness in accommodating me and making easy contacting the subjects.
6. Muhammad Ridwan Andi Purnomo., ST., M.Sc., Ph.D as Head of International Program Industrial Engineering Universitas Islam Indonesia
7. Dr. Drs. Imam Djati Widodo, M.Eng.Sc. as dean of Industrial Technology Faculty, Universitas Islam Indonesia
8. All of my friends from Industrial Engineering International Program especially batch 2013 for the support, motivation even annoying that cannot be mentioned one by one.
9. Mrs. Diana and Mrs. Devi that patiently help the students, especially the author.
10. Jaler, Hanif, and others who I do not know the name for helping in taking data.
11. Tom’s Warrior: Sasa, Ekky, Jefin, Bari, Mbak Nanda, Arum, Ken, Yoga, Enggang, for supporting and unconditional motivation, glad to know you all.

The Authors also thanks to all of concerned parties that cannot be mentioned one by one who have helped me in completing this report. Hopefully, the goods which are given by all parties to the Author will be replied by the kindness from Allah.

Finally, the Author realizes that there are still shortcomings as well as weaknesses in this report, so the building suggestions and critics are fully expected. The author hopes this paper would bring advantages for everyone who reads this.

Wassalamualaikum Wr. Wb.

Yogyakarta, April 20th, 2018

Faradhina Azzahra

ABSTRACT

The result of national examination in Senior High School students of Indonesia fluctuated for the last 3 years particularly in Yogyakarta. This examination is one of the national indicators for the achievement in the knowledge comprehension among the student on the certain subjects. Physics is a subject tested producing digression on the average score for the last 3 years; 2015-2017. Several factors that contribute are learning process method, environment, subject, teacher, and student's cognitive manner. However, latest factor has a high effect on accomplishing a success. The objective of this study is to investigate the mental fatigue of students in taking a part of teaching-learning process of Physics by analyzing the brain activity at cognitive system in 4 sessions. It is the combination of learning method (autodidact and non-autodidact) and condition (late morning and afternoon). An experimental study was conducted at laboratory to record beta, alpha and theta wave of brain that produced by electroencephalograph (EEG). Four students of Senior High School were participated in this study to attend a learning process of Physics for 90 minutes in each session. Non-parametric statistical analysis was performed to test the hypothesis. The result of this study showed that the autodidact learning method in the late morning for 54.25 minutes had a better performance in learning the Physic subject.

Keywords-electroencephalograph; mental fatigue; student; senior high school; Physics

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Education is a responsibility for people, which all people have a right to get and hope for always developing in their knowledge. Based on Aristoteles cited by Sutrisno (2012), in order to get a good life, human needs to get education. Education is an intentional lesson activity in order to get virtuous personality both in spiritual and physical (Sutrisno, 2012). Family is a first place where human get education called informal education. Informal education is an education that is exposed to a human from daily experience. Besides, there is also non-formal education which is education coming from society, and formal education which is education gotten from school. Formal education is an education that is received by human generally from 9 to 12 years old in elementary school, 13 to 15 years old in junior high school, 16 to 18 years old in senior high school, and the older years in university (Kurniawati, 2013).

For elementary school, junior high school, and senior high school, it is stipulated in government regulation number 19 of 2005 paragraph 63:1, kind of education assessment for student is based on 3 kinds of assessment, which are learning outcomes by educators, by educational units, and by the government (*Peraturan Pemerintah Republik Indonesia*, 2005). Assessment of learning outcomes by government is defined in regulation number 19 of 2005 paragraph 66:1, it is aimed to assess the competence achievement nationally on certain subjects that conducted in the form of national examinations (*Peraturan Pemerintah*

Republik Indonesia, 2005). Based on the regulation, it is indicated that national examination is one of education measurement that has to be achieved by student.

In senior high school, the students need to choose between science and social major. In science major, the subjects that included in national examination is Bahasa, English, Mathematics, Physic, Chemistry, and Biology. Based on record of Ministry of Education and Culture (2017), the result of national examination in Indonesia has been fluctuating for the last 3 years especially in D.I. Yogyakarta. At public senior high school in Yogyakarta, the region that had the highest score of national examination in D.I.Y, the score for English, Chemistry, and Biology subject decreased in 2016 and increased in 2017. For Mathematics subject, the score was significantly increased in 2016 and decreased in 2017. Physics is the only subject that has experienced the decreasing in each year for last 3 years, whereas 12% decreasing in 2016, and 2% decreasing in 2017. The score for each subject can be seen in Table 1.1 below.

Table 1.1 Result of National Examination in Yogyakarta for Science Class
(Source: https://puspendik.kemdikbud.go.id/hasil-un/)

Subjects	**Score**		
	2015	**2016**	**2017**
Indonesian	86.38	77.87	84.83
English	75.11	70.41	78.13
Mathematics	66.28	68.13	68.04
Physics	75.69	66.98	65.40
Chemistry	73.54	66.99	74.49
Biology	75.02	70.58	74.61

If it is compared with Bantul, as a region that had the second highest score of national examination in D.I.Y, the score for Physics subject in public senior high school are decreased in 2016 as much as 25% but able to increase in 2017 as much as 3%. However, even the score for Physics subject in Bantul was increased in 2017 and the score for Physics in Yogyakarta was decreased in last 3 years, the average score for Physics in Yogyakarta is still higher than Bantul in each year.

Suswanto (2017), a counselling teacher in SMA N 6 Yogyakarta, said that there are several factors influencing the score of students based on learning process in class, which are subject, teacher, and students (personal communication, August 8, 2017). Hartanti, a physics teacher in SMA N 1 Kasihan, added other factor, which is environmental (personal communication, August 28, 2017). It can be concluded by combining both experts and stated by Slameto (2013) that the factors influencing the result score of students based on learning process in class are environment, subject, teacher, and student. Environment's factor includes noisy, lighting, temperature, and others. Subject's factor covers the difficultness of the subject. Teacher's factor covers on how the teacher explaining the subject. Student's factor covers the motivation and concentration that follows the learning process in class.

Environmental factor can be measured by the condition of the class and facilities provided by the school. The number of students in each class in SMA N 6 Yogyakarta are ± 28 students, while in SMA N 1 Kasihan are ± 23 students. The number of student in SMA N 6 Yogyakarta is fewer than in SMA N 1 Kasihan. The smaller group of learning process in class is able to make the students more concentrate with the lesson. Thus, the condition of the class in SMA N 1 Kasihan is more conducive. Besides, the classes' facilities in SMA N 6 Yogyakarta is similar with facilities in SMA N 1 Kasihan. The difference is SMA N 1 Kasihan provides class with 1 fan and 2 AC in each class while SMA N 6 Yogyakarta provides class only with 1 fan. The ACs in SMA N 1 Kasihan are able to maintain the temperature in good condition. As the object of comparison, noisy level in-class room of SMAN 6 Yogyakarta is 69.77 dBa and out-class room is 72.21 dBa, while noise level in-class room of SMAN 1 Kasihan is 72.21 dBa and out-class room is 72.16 dBa. The temperature in-class room of SMAN 6 Yogyakarta is 30.2 ºC and SMAN 1 Kasihan is 25.9 ºC. The lighting level in-class room of SMAN 6 Yogyakarta is 87 Lux and SMAN 1 Kasihan is 79 Lux. Overall, based on noise level, temperature, and lighting level SMAN 6 Yogyakarta and SMAN 1 Kasihan is almost same. Nevertheless, SMAN 1 Kasihan facility is slightly better than SMAN 6 Yogyakarta.

Subject's factor covers difficultness of the matter. Since the focus of this research is Physics, then there is no difference in both high school. The syllabus of physics is the same in both schools since it has been arranged in curriculum. Besides, *Dinas Pendidikan* has set the rule in which all of teachers should arrange and attend MGMP (*Musyawarah Guru Mata Pelajaran*). MGMP is an organization that was formed by teachers for communication forum in order to solve any problems faced by each teacher and to provide good coordination among the teachers in the same subject.

Teacher's factor covers on how the teacher explaining the matter. Physics teachers in both school basically have same method in teaching process. When teachers explain the lesson, teachers use LCD and several physics animation in order to attract the attention of the student. When teachers give the homework, teachers would ask several students to go before the class and write answer down on the white board in the next day.

Based on Kinantie et al., (2012), students in senior high school especially in 3rd grade are experiencing the stress in upcoming of national examination. Based on the result of research, 4.15% of students categorized as normal, 15.2% of students categorized as light stress, 49.74% of students categorized as medium stress, 30.05% of students categorized as heavy stress, and 0.52% of students categorized as very strong in stress.

Based on Djemari & Kartowagiran (2009), national examination gives impact to students. National examination will lead to students to add more time for studying. It was recorded that 81% of students in school that categorized as good school and 65% students in school that categorized as low school were added with more time for studying. Unfortunately, 41% students were experiencing fatigue in the upcoming of national examination.

In fact, students of SMA N 1 Kasihan are offered to learn the Physics for 2 x 45 minutes in a day which is repeated for 3 times in a week. The physics are scheduled randomly between school hours where students are asked to go to school 5 days in a week (Saturday-Sunday are free). School hours for 3rd grade student on Monday to Thursday is set from 07:15 until 15:30 WIB while on Friday is set from 07:15 until 13:25 WIB.

According to those facts, students at SMA N 1 Kasihan are asked to study the Physics for 90 minutes continuously, whereas Wascher et al (2014) stated that prolonged periods of cognitive activity lead to mental fatigue. Mental fatigue is a decline of cognitive performance that is able to reduce working memory performance and decrease the ability to focus attention. Mental fatigue is included as a physiological state that arises when someone do a continuous task for a long time or when someone do a task requiring focus and attention. Charbonnier et al., (2016) explained the consequence of someone reaches mental fatigue state is a difficulty to get and process the information in a fast and efficient way.

Mental fatigue is able to be analysed by observing the electric activity in brain by using Electroencephalograph (EEG). Spectral EEG measurement had been proposed to be valid and reliable indicators of mental fatigue. A shift of EEG power toward Delta, Theta, Alpha, and Beta might be related to a decrease in the level of arousal one core aspect of mental fatigue (Wascher et al., 2014).

Consequently, the objective of this study is to investigate the mental fatigue of science students that will face national examination in taking a part of teaching-learning process of Physics by analyzing the brain activity at cognitive system. Brain activity is recorded by using EEG and the experiment will be carried out at Laboratory of Computer Science and Electronics, Universitas Gadjah Mada. The temperature and lighting will be set to be similar as classroom in SMA N 1 Kasihan. In addition, mental fatigue investigation will be performed by combining four different variables which are learning methods (autodidact and non-autodidact) and conditions (late morning and afternoon) to find the best learning method and condition for learning the Physics.

1.2 PROBLEM FORMULATION

The problem formulations of this research are:

1. How are the changes of Theta, Alpha, and Beta waves in brain activity on students while studying the Physics by using book and video in the late morning and afternoon based on Electroencephalograph (EEG) analysis?
2. How much of mental fatigue level on students while studying the Physics by autodidact and non-autodidact in the late morning and afternoon?

1.3 RESEARCH OBJECTIVES

The objectives of this research are:

1. Identifying the changes of Theta, Alpha, and Beta waves in brain activity on EEG while studying the Physics using book and video in the late morning and afternoon.
2. Analysing the mental fatigue level of students while studying the Physics using book and video in the late morning and afternoon.

1.4 LIMITATION AND ASSUMPTION OF RESEARCH

Limitations in this study are determined in order to make the research conducted not too broad and limp from existing research topics. The boundaries of that problem are:

a. Objectively measured by using EEG assessment based on RMS (Root Mean Square) of amplitude.
b. Focused on the mental fatigue aspect of learning the Physics by Senior High School's student.
c. Focused on autodidact and non-autodidact learning method in the late morning and afternoon as the comparison.

Assumption in this study is determined in order to make research conducted not too broad from existing research topics and research conducted naturally without any experimental setting. In this study, although the experiment non-autodidact learning process is done without teacher due to difficultness for having a teacher, it is assumed same as non-autodidact learning process in class. The laboratory for experiment's place is assumed same as class condition.

1.5 BENEFIT OF RESEARCH

The researcher is expected this research is able to give some benefits, which are:

1. This research is expected to be an input and evaluation for school and teachers to manage teaching method in order to make mental fatigue of students is not on the maximum state. Therefore, the students can get full attention in class and accept all information given.
2. This research is expected to be used as a reading reference to increase knowledge of the readers. Then, the analysis of research can be used by society to prevent and control the factors that influence mental fatigue. Moreover, this research also can be seen as a reference for the next research since the scope still needs to be developed.

1.6 SYSTEMATICAL WRITING

Systematic of thesis writing is written in order to make this research more structured and easy to be read. Therefore, systematically the research has six chapters as follows:

First, chapter one is introduction that contains of problem statement, problem background, problem formulation, research objective, scope of problem, research benefit, and systematical writing.

Then, chapter two is literature review written about inductive and deductive study. Inductive study is primarily important to determine the literature study of the previous research. Deductive study suggests the basic supporting theories. Literature review contains both concept and basic principles that needed to solve research problems. It also includes studies result that have been done before by other researchers that related with the research undertaken.

Next, chapter three is research methodology that explains the steps for conducting the research in order to keep researcher focused on the objective of this research. This chapter explains the detailed object and focus of research also the conceptual model of the research.

Chapter four is data collecting and processing described the data collection and processing, analysis and results, including images and graphics obtained. This chapter is a reference for the discussion of the results that will be written in Chapter five.

Moreover, fifth chapter explains the discussion about the result of the previous chapter. In this chapter, there will be the core discussion in order to get a comprehensive understanding about the whole research.

Finally, chapter six is conclusion and recommendation that concludes the overall result of the research and show the suggestion. Suggestion related to the current study in purpose of the advancement in the future research is given based on the limitations of the current research. After the research summarized and recommendation provided, the next part will contain References and appendices.

CHAPTER II

LITERATURES REVIEW

2.1 INTRODUCTION

In this chapter, there will be explained about literature study. Literature study consists of basic theory for the research and several previous researches that related with the research topic. The research articles were derived from reputable journals or seminar proceedings. The literature review is aimed to do study mapping related to the research issue while the outcome of the research is taken from the further research to continue of improving the existing researches.

The literature study will be explained about definition and theory of fatigue, mental fatigue, and EEG. Besides, it also contained several latest researches that related with EEG mental fatigue.

2.2 FATIGUE

Fatigue is a common symptom in the general population. Many peoples experience fatigue related to lifestyle or situational factors, but actually fatigue is a consequence of medial or psychiatric illness (Jason et al., 2010). Based on English Oxford Dictionary, the term of fatigue means to exhaust as with riding or working, to weary or to harass (Ream et al., 1996).

Fatigue is the primary symptom of chronic fatigue syndrome (CFS), and is associated with a number of acute and chronic illnesses, such as rheumatoid arthritis, cancer, and multiple sclerosis. A number of conceptualizations of fatigue have considered it along dualistic lines (Shen et al., 2006).

a. Acute vs. chronic fatigue

   There are two types of fatigue which are acute and chronic. Acute fatigue is normally happened in healthy people. It is only in short duration which is able to decrease after a rest, exercise, and/or stress management. It has minor impact on daily activities (Shen et al., 2006). In the other hand, chronic fatigue is an abnormal, unusual, or excessive fatigue. It has greater intensity and longer duration, causing severe impairments to an individual's functional activity and quality of life (Jason et al., 2010).

b. Physiological vs. psychological fatigue

   Fatigue is also able to be classified into physiological and psychological fatigue. Physiological fatigue is happened because of excessive energy consumption; or the depletion of hormones, neurotransmitters, or essential physiological substrates. It is a failure of the functional organ that is usually associated with fever, infection, anemia, sleep disturbance, or pregnancy. Besides, psychological fatigue is a state when someone's motivation decreased. It is associated with stress, depression, or anxiety (Shen et al., 2006).

c. Central vs. peripheral fatigue

   Fatigue is also divided into 2 models, which is central and peripheral models fatigue. Central models of fatigue mean a malfunction in CNS (central nervous system). The example of malfunction in CNS is impaired transmission between the CNS and the peripheral nervous system or dysfunction of CNS. In the other hand, peripheral models of fatigue mean a dysfunction of peripheral nervous system. The example of dysfunction in peripheral nervous system is impaired neuromuscular transmission at the motor-endplate. However, the term of central fatigue is usually related to a psychological fatigue while peripheral is related to physical fatigue (Shen et al., 2006).

2.3 MENTAL FATIGUE

Mental fatigue is included as a psychological state that arises when someone do a continuous task for a long time or when someone does a task requiring focus and attention. When someone reaches mental fatigue state, the consequence is a difficulty to get and process the information in a fast and efficient way (Charbonnier et al., 2016). Prolonged periods of cognitive activity lead to mental fatigue. Mental fatigue is a decline of cognitive performance that is able to reduce working memory performance and decrease the ability to focus attention (Wascher et al., 2014).

Based on Lowenthal (2006) in Ariani (2009), there are 4 factor influencing mental fatigue, which are:

1. Circadian Rhythm Factor

   Body has natural cycle that will continue to recur for 24 hours called as circadian rhythm. Circadian rhythms are physical, mental, and behavioural changes that follow a daily cycle. Circadian rhythms are important in determining the sleeping and feeding patterns of all animals, including human being. It organizes pattern of sleep, body temperature, digestion function, etc. it responds primarily to light and darkness in an organism's environment. Sleeping at night and being awake during the day is an example of a light-related circadian rhythm. According to Kim & Duffy (2018), changes of sleeping and being awake cycle can result in an inability to fall asleep at the desired time, difficulty remaining asleep, or difficulty remaining awake throughout the desired wake episode. That mismatch called circadian rhythm sleep-wake disorders that affect to sleep disruption.

2. Sleep Quality Factor

   Commonly, the average time to sleep in a day is between 6-8 hours for adult. They who do not sleep for less and more than 6-8 hours will lead to sleepiness. For 6-8 hours, human need to have good sleep quality. Good sleep quality is beneficial in positive outcomes such as better health, less daytime sleepiness, and better psychological function.

3. Health Factor

   Health is a prosperous state of body, soul, and social that enables for every human to live productively. Health maintenance is needed to overcome and prevent health problems that require examination or treatment. The examples of health problem that lead to fatigue are anemia, diabetes, thyroid hormone problem, rheumatism, etc. Beside those medical problems, fatigue can also occur in overweight or lack of weight human body. Being overweight can make body to work harder in doing several activities, while being lack of weight means weak muscle strength that leads to feel fatigue faster.

4. Work Factor

   Rodahl (1989) and Manuaba (2000) stated that work factor was divided into external and internal factors.

   a. External Factors

      It is influenced by factors from the external body of workers which are task demand, work organization, and work environment.

      - Task. It is divided to physical and mental task. Physical task is task from work stations, layout in workplace, equipment and tools, condition in the workplace, lifting and manual handling, supporting equipment, display control work procedures, etc. Meanwhile, mental task are complexity, difficulty of job that influence the worker’s emotion, responsibility, etc.

- Work organization. It includes work hour, break time, shift work, and salary system.
- Work environment. It includes physical work environment, chemical environment, biological work environment, and psychological work environment.

b. Internal Factors

It is factors from the internal by of human which are somatic and psychology factors.

- Somatic factors; gender, age, body size, body fitness, nutrition.
- Psychology factors; motivation, perception, self-confident, willingness, satisfaction, etc.

Moreover, the factor influencing mental fatigue during works can be divided into 6 factors (NASA, 1986), which are:

a. Mental Demand

Mental demand is about mental and perceptual activity required (e.g., thinking, deciding, calculating, and remembering, looking, searching, etc.) whether the task easy or demanding, simple or complex, exacting or forgiving.

b. Physical Demand

Physical demand is about the physical activity required (e.g. pushing, pulling, turning, controlling, activating, etc.) whether the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious.

c. Temporal Demand

Temporal demand is about the time pressure felt due to the rate or pace at which the tasks or task elements occurred whether the pace slow and leisurely or rapid and frantic.

d. Performance

Performance is about how successful in accomplishing the goals of the task set by the experimenter and how satisfied in accomplishing these goals.

e. Effort

Effort is about how hard needed to work (mentally and physically) for accomplishing the level of performance.

f. Frustration

Frustration is about how insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent felt during the task.

Nolan et al., (2015) recommended to estimate the level of energy for a day and the energy required for the activities that is needed to do to reduce fatigue. It is suggested to stay within the limits of the estimated energy. If the energy is expended more than estimated energy, it is called over-doing and risk a 'crash'. If the energy is expended less than estimated energy, it is called under-active and that is contributing to the feelings of fatigue. So, it is important to have a balance between what is needed and wanted to do, achieve a balance through the activities that engage in (Nolan et al., 2015).

There are some strategies in order to maximize the energy in learning (Nolan et al., 2015) , which are:

a. Prioritising what is needed and wanted to do.
b. Planning and managing time how the task can be finished (ex: writing a To-Do list).
c. Knowing the limits and set achievable goals.
d. Simplifying activities and being organised to use less energy.
e. Having down time to relax and rest.
f. Setting up the right environment by considering where the best place, comfortable temperature, fresh air circulating, etc.

g. Strategies for managing fatigue before, during, and after the examination day: Two or three weeks before the exams are probably the most important times to manage the fatigue and make sure to get enough rest. After an exam, a break, rest, and a light exercise are helpful to recharge the energy and relieve tired muscles.
h. Eat good nutrition and do some exercises for taking care the physical body

2.4 MEASUREMENT OF MENTAL FATIGUE

The measurement of mental fatigue can be divided into subjective measurement and objective measurement (Milar, 2012). The subjective measurement is measuring based on what people say about what they actually experience. On the other hand, objective measurement is based on how well people perform a task without considering what they experience while performing the task.

Milar (2012) and Kamaliana et al., (2016) explained that there are several well established subjective measurement of mental fatigue, including:

a. Stanford Sleepiness Scale (SSS). It measure the level of alertness which respondent is required to choose which conditions based on seven statements that describe his/her feelings and alertness level at that time.
b. Visual Analogue Scale (VAS). It is straight horizontal line of fixed length where the ends are defined as the extreme limits of the parameter to be measured oriented from the left (worst) to the right (best).
c. The Karolinska Sleepiness Scale (KSS). It is helpful in evaluating the changes in response where there is a 9-point scale (1 = extremely alert, 2 = very alert, 3 = alert, 4 = rather alert, 5 = neither alert nor sleepy, 6 = some signs of sleepiness, 7 = sleepy, but no difficulty remaining awake, 8 = sleepy but some difficulty to keep awake, and 9 = extremely sleepy, great difficulty to keep awake, fighting sleep).

d. Samn-Perelli Seven-point Fatigue Scale (SPS). It consists of seven numbered descriptors, ranging from 1 = fully alert, wide awake to 7 = complete exhausted, unable to function.

Then, objective measurement of human mental fatigue also can be measure by several techniques, which are:

a. Electroencephalogram or EEG is a tools to collect the time-varying spatial potential distribution over the scalp produced by the cortical brain activity (Charbonnier et al, 2016; Chen et al., 2014; Wascher et al., 2014; Yin & Zhang, 2017).
b. Electrooculography or EOG is a tools to analysing the variation of the potential distribution across the eye, that returns information about the eye blinks and the eye movements (Roy et al., 2014; Zhao et al., 2012).
c. Electrocardiograph or ECG is a tools to measure the activity of heart rate variation (Zhao et al., 2012).

2.5 ELECTROENCEPHALOGRAPH

Electroencephalography (EEG) is the neurophysiologic measurement of the electrical activity of the brain by recording from electrodes placed on the scalp. Electrode placement is accomplished by measuring the scalp. Electrode locations and names are specified by the International 10–20 system (Cheng & Hsu, 2011).

The International 10-20 system is an internationally recognized method to describe the location of scalp electrodes. Jasper (1958) in Herwig et al., (2003) stated that the International 10-20 system is commonly used for EEG electrode placement and for correlating external skull location to underlying cortical areas. The numbers ‘10’ and ‘20’ refer to the fact that the distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull. The location of scalp electrodes based on International 10-20 system is shown in Figure 2.1 below.

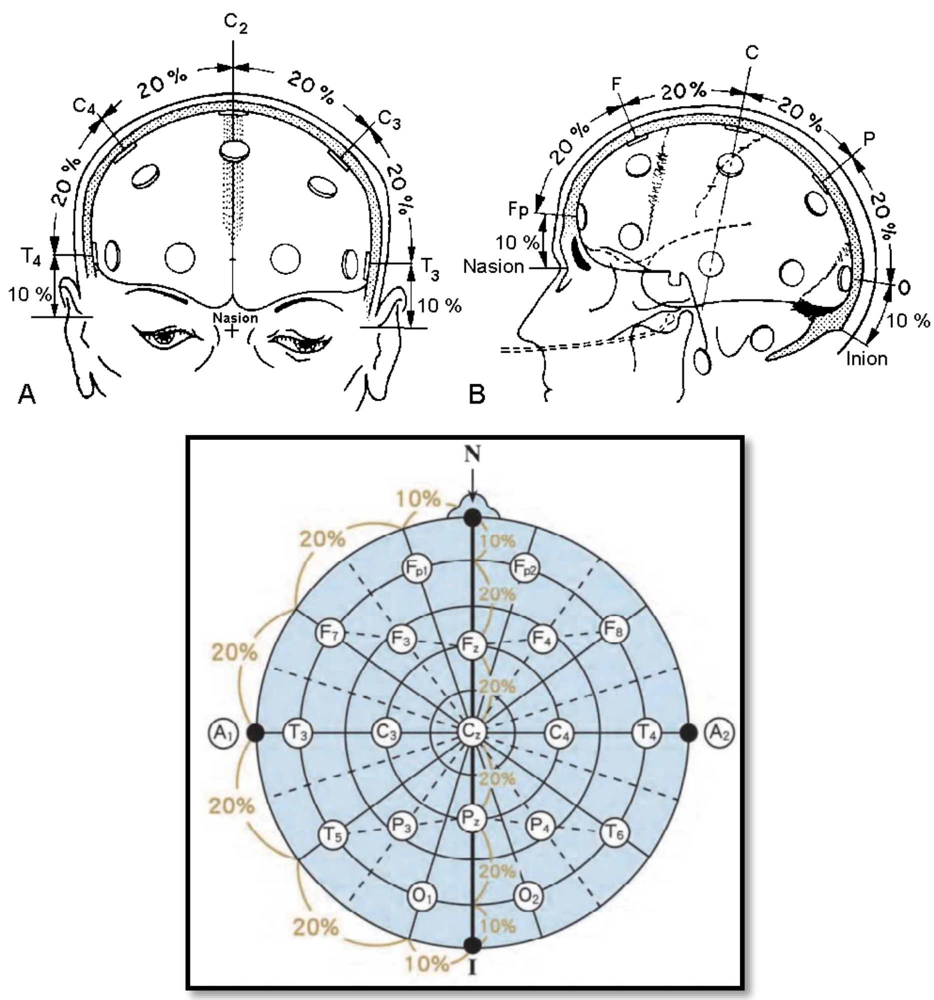


Figure 2.1 International 10-20 System, Electrode Position
(Source: Cheng & Hsu, 2011)

Each site has a letter to identify the lobe and a number to identify the hemisphere location. The letter 'F' means frontal lobe, 'T' means temporal lobe, 'P' means parietal lobe, and 'O' means occipital lobe. Meanwhile, there is no central lobe exists, the 'C' letter is used for identification central of scalp only. The 'z' means zero that refers to an electrode placed on the middle line. Even numbers (2, 4, 6, and 8) refer to electrode positions on the right hemisphere. Odd numbers (1, 3, 5, and 7) refer to electrode positions on the left hemisphere.

Four anatomical landmarks are used for the essential positioning of the electrodes; first, the 'N' letter refers to nasion which is the point between the forehead and the nose; second, the 'I' letter refers to inion which is the lowest point of the skull from the back of the head and is normally indicated by a prominent bump; then, the 'A' letter refer to pre auricular points anterior to the ear.

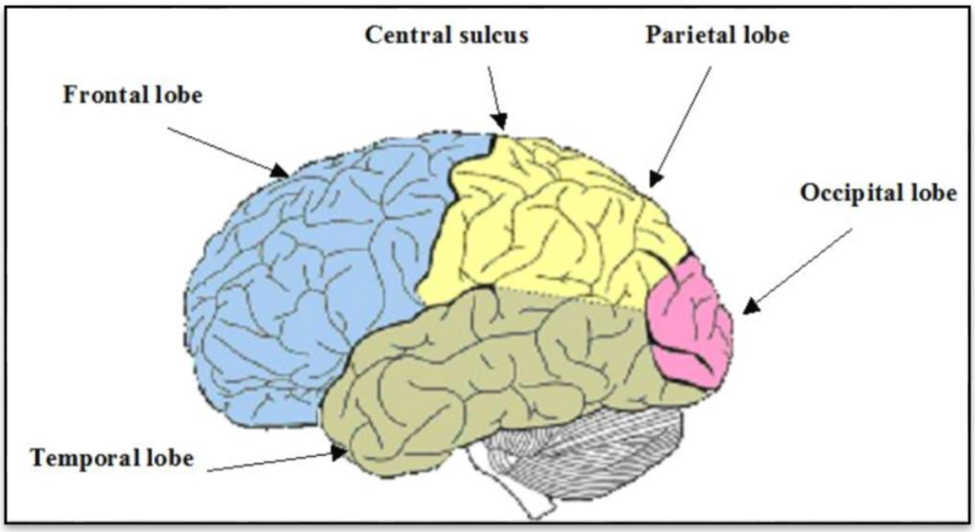


Figure 2.2 The Cerebral Cortex
(Source: Cheng & Hsu, 2011)

The frontal lobe is an area in the brain of mammals located at the front of each cerebral hemisphere. In the human brain, the precentral gyrus and the related cortical tissue that folds into the central sulcus comprise the primary motor cortex, which controls voluntary movements of specific body parts associated with areas of the gyrus. The frontal lobes have been found to play a part in impulse control, judgment, language production, working memory, motor function, problem solving, sexual behavior, socialization, and spontaneity. The frontal lobes assist in planning, coordinating, controlling, and executing behavior. The so-called executive functions of the frontal lobes involve the ability to recognize future consequences resulting from current actions, to choose between good and bad actions (or better and best), override and suppress unacceptable social responses, and determine similarities and differences between things or events (Cheng & Hsu, 2011).

The parietal lobe is located just behind the frontal region. The parietal lobe integrates sensory information, specifically dealing with spatial sense and navigation. Another function is comprehending numbers and the manipulation of objects. This area is responsible for sensation, or the ability of the brain to use senses to detect different environmental entities. Damage to this lobe can cause eyesight problems, left and right hemisphere confusion (can't tell objects left from right), inability to perform mathematical solutions, reading and writing problems, and symbol comprehension (Cheng & Hsu, 2011).

The temporal lobes are part of the cerebrum. They lie at the sides of the brain, beneath the lateral or Sylvian fissure. The temporal lobes are where the thumbs would be. The temporal lobe is involved in auditory processing and is home to the primary auditory cortex. It is also heavily involved in semantics both in speech and vision. The temporal lobe contains the hippocampus and is therefore involved in memory formation as well. The functions of the left temporal lobe are not limited to low-level perception but extend to comprehension, naming, verbal memory and other language functions (Cheng & Hsu, 2011).

The occipital lobe is the visual processing center of the mammalian brain, containing most of the anatomical region of the visual cortex. There are many extra striate regions, and these are specialized for different visual tasks, such as visuospatial processing, color discrimination and motion perception. Retinal sensors convey stimuli through the optic tracts to the lateral geniculate bodies, where optic radiations continue to the visual cortex. Each visual cortex receives raw sensory information from the outside half of the retina on the same side of the head and from the inside half of the retina on the other side of the head (Cheng & Hsu, 2011).

EEG records the brain waves that divided into five major brain waves distinguished by their different frequency ranges. These frequency brain are called alpha (α), theta (θ), beta (β), delta (δ), and gamma (γ) (Sanei & Chambers, 2007):

a. Delta waves lie within the range of 0.5 – 4 Hz. These waves are primarily associated with deep sleep and may be present in the waking state.

b. Theta waves lie within the range of 4 – 8 Hz. Theta waves appear as consciousness slips toward drowsiness. Theta waves have been associated with access to unconscious material, creative inspiration, and deep meditation.

c. Alpha waves have frequency within the range of 8-13 Hz. It has been thought to indicate both a relaxed awareness without any attention or concentration. Most subject produce some alpha waves with their eyes closed. It is reduced or eliminated by opening the eyes, by hearing unfamiliar sounds, by anxiety, or mental concentration or attention. Albert Einstein could solve complex mathematical problems while remaining in the alpha state, although generally beta and theta waves are also present.

d. A beta waves is the electrical activity of the brain varying within the range of 13-30 Hz. A beta wave is the usual waking rhythm of the brain associated with active thinking, active attention, focus on the outside world, or solving concrete problems, and is found in normal adults. A high-level beta wave may be acquired when a human is in a panic state.

e. The frequency above 30 Hz (mainly up to 45 Hz) correspond to the gamma range (sometime called the fast beta wave). Although the amplitudes of these rhythms are very low and their occurrence is rare, detection of these rhythms can be used for confirmation of certain brain disease.

2.6 EEG MENTAL FATIGUE

It has been already done by several studies that EEG is a sensitive tool in fluctuation of vigilance and has been shown mental fatigue that able to lowering performance. Alpha and theta rhythms significantly increased, while the relative power of the beta rhythm significantly decreased in relative power (Babiloni, 2012) or amplitude (Wascher et al., 2014).

There were a research that used EEG for measuring mental fatigue caused by mobile 3D and correlate with natural sound (Mun et al., 2014), measuring mental fatigue focused in fatigue level after watching 3DTV (Chen et al., 2013, 2014), measuring mental fatigue related attentional process by doing fictitious experiment (Boksem et al., 2005; Charbonnier et al., 2016; Käthner et al., 2014), measuring mental fatigue then relate it with motivation and action monitoring (Boksem et al., 2006), measuring mental fatigue in different group of age (Arnau et al., 2017), measuring driver mental fatigue (Zhao et al., 2012), and also measuring length of time to get mental fatigue in attentional process (Wascher et al., 2014).

Mun et al., (2014) wrote a research in order is to investigate auditory ERP (event related potential) correlates of mental fatigue caused by mobile 3D viewing with the object is mental fatigue caused by mobile 3D viewing (entitled "The Call of the Wild", 2009) for approximately 80 min. The 27 people are participated between 19 and 28 years. The experiment is done by doing selective attention task. Forty natural sounds were randomly selected from a natural sound pool of 100 environmental sounds and presented to each participant on either their left or right side. Forty sounds were included in five blocks. Participants were instructed in the monitor which direction the participant should focus and ignore. The participant were also instructed to press the spacebar on the keyboard whenever the participants detected the sound presented on the attended side as accurately and as rapidly as possible, while ignoring the sounds on the other side. The participants were also asked to mentally count (not using their fingers) and report the number of the presented sounds per block.

Chen et al. (2014) evaluated the level of 3DTV fatigue and wrote into a research. The research was comparing between the gravity frequency and power spectral entropy of EEG result using t-test. Then, establish evaluation model based on the subjective questionnaire and 3DTV fatigue level (gravity frequency and power spectral entropy). Twenty-five dominated college students were participated. EEG data was recorded to participants in the eyes-closed resting state for 5 min before watching TV. Then subject were instructed to watch 2D/3D television for about 60 min without collecting EEG data (not using EEG cap). Following that, another 5 minutes EEG data was immediately recorded in the eye-closed resting state under the same conditions. The subjective questionnaire of fatigue was given. The result showed, based on questionnaire, the main value of the subjective fatigue increased more significantly in 3D group than 2D group. Based on comparison of gravity frequency and power spectral entropy between 2D and 3D, both parameter in 3D changed more significantly than the 2D. It concludes that, compared with watching 2DTV, 3DTV viewing will cause more fatigue and discomfort.

Chen et al., (2013) also evaluated the level of 3DTV fatigue. Ten college students were participated in this research with the age between 20 and 24 years old. EEG data was recorded in the eyes-closed resting state for 5 min before watching TV. Then subject were then instructed to watch 2D/3D television for about 60 min without collecting EEG data (not using EEG cap). Following that, another 5 minutes EEG data was immediately recorded in the eye-closed resting state under the same conditions. There was no significant change of EEG signals in prefrontal and frontal regions as a result of watching 2DTV, but a change was obvious when observing data from 3DTV.

Charbonnier et al. (2016) wrote a research with the objective to present an indicator to monitor operator's mental fatigue and tested by EEG and EOG. Fifteen healthy people were participated with the mean age 25 ± 3.5 years old. Participants had to memorize a list of sequential digits visually presented on a computer screen. Then, a probe item flanked with question marks was displayed. The participant has to answer as quickly and as accurately as possible whether the probe was present or not in the memories list. The experiment lasted for 90 minutes that divided into 6 blocks and achieved 750 trials. The participants had to assess their mental fatigue using Karolinska Sleepiness Scale before, in the middle, and at the end of the experiment. EEG activity and EOG activity also done while the experiment running. The paper showed that it is possible to assess mental fatigue using EEG signals Ocular indices through EOG are another efficient way to assess fatigue.

Boksem et al., 2005 wrote a research in order to examine how mental fatigue affects the attentional process. Seventeen university students were participated as the subject between 18 and 26 years old. The participant performs a visual attention task continuously for 3 hours without rest. Experiment: begin with the presentation of a memory set of two letters. Next, a cue frame is presented to indicate which display positions were relevant. Thereafter, participants were randomly presented a series of 160 stimulus displays (consisting 1 block). The participant responded the stimulus whether the stimulus are relevant target, relevant non-target, irrelevant target, or irrelevant non-target. They were presented with 50 block, lasting for 3 hours in total. Before the task and after every 10th block, subjects received a question about the level of resistance they felt (aversion scale) between zero and ten. During the task, EEG was recorded using 30 electrodes attached to an electro cap. The paper concluded that fatigued people is increased distractibility as well as the decrease in flexibility.

Käthner et al. (2014) wrote a research in order to revealing electrophysiological indicators of mental workload and fatigue during prolonged usage of a P300 brain-computer interface. Twenty-two people were participated with the mean of age 24.9 years old. In the experiment, participants performed P300 BCI spelling task. During the experiment, two concurrent stories were presented over headphones. One story was presented over the left and another over the right headphone speaker. The experiment was divided into 2 kinds, the medium and high workload condition. For medium workload condition, participants were instructed to ignore the stories, while for high workload condition, participants were instructed to pay attention to the context of both stories. After the stories stopped, participants answered 6 questions about the content of the stories to ensure successful manipulation of workload. Then, subjective workload was asked based on NASA-TLX. Before and after the experiment, the level of fatigue was assessed with a visual analogue scale (VAS). The experiment revealed that participants spelled better in the medium workload condition than in the high workload condition. P300 amplitude was significantly reduced in the high workload condition as compared to the medium and no significant difference in latency were found. The alpha and theta power were increased in both workload condition, but there were no significant differences between the medium and high workload condition.

Boksem et al. (2006) conduct a research with purpose to examine whether the effects of mental fatigue on behaviour are due to reduced monitoring as indexed by the error related negativity (Ne/ERN), N2, and contingent negative variation (CNV) event-related potential (ERP) components. Besides, the research has a purpose to examine the relationship between fatigue and (lack of) motivation to continue task performance. Nineteen university students were participated between 18 and 26 years of age. The participant were presented a stimulus consisted of an H or an S. Participants were instructed to make a left-hand button-press response if the stimulus was an H, and a right hand button-press response if the stimulus was an S. Stimuli remained on the screen until a response was made or until 1200 mas had elapsed. After this there was a 500 ms interval, in which subject had the opportunity to correct their erroneous response by giving the correct response. Finally, there was an interval of 400-600 ms before the start of the next trial. Before the start, the subject needed to be trained for 15 min. The experiment was lasted for 2h and 20 min. Subjects completed between 3500 and 4000 trials during the entire experiment. Before the start of the last 20 min, a text was displayed on screen that informed the subject that from that time on, his performance would be compared to that of other subjects and that the subjects who performed best would receive €25 extra payment. Based on the experiment, the researchers were able to conclude that Subject clearly exhibited impaired action monitoring and response preparation when they became fatigues. This impairment can be alleviated by increasing reward. When the observed rewards become insufficient, subject disengage from the task, feeling, fatigue. When rewards are increased at the end of the task, effort and reward are once again balanced, resulting in better performance.

Arnau et al. (2017) wrote a research in order to investigate whether the older participants were differentially affected by mental fatigue compared to younger participants. Fourteen older adults were compared to 13 younger adults. Older adults with range age were 55 to 70 years; and younger adults with range age were 20 to 30 years. The group of age were examined with same experiment where stimuli were presented either left or right from a fixation cross. The shape of the stimuli could be either a square or a diamond. The participants had to respond to the shape of the shape of the stimuli by pressing force keys, whereby the presentation side of the stimuli had to be ignored. The result showed that there is no differences between the age groups were found in behaviour, but electrophysiological measures provide some evidence that older adults in our study were differentially affected by time on task. In frontal theta power became larger for older, compared to younger adults. This may indicate strain due to task demands, eventually resulting from the deployment of compensatory processes. Occipital alpha, which has been linked to internally oriented brain states, saturates faster in younger adults. It thus may be, that especially the younger participants' performance deteriorated due to the monotonous nature of the task itself.

Zhao et al., (2012) wrote a research in order to estimate driving mental fatigue. Thirty male of student colleges with mean age 25.8 years were participated. Using driving simulators lasted approximately 90min, consist of a car frame with a built-in steering wheel, gas and brake pedal, clutch, manual shift and a horn and turn signal. The visual display is visual reality (VR) with engine noise and nearby traffic noise. To assess the sustained attention level of drivers, subject were requested to perform an Oddball task at the beginning and end pf the driving task which asked the participant to respond to target stimuli. Then, the subject were asked about their self-report. Relative power spectra of EEG, amplitude of P300, the ApEn of ECG showed statistically significant differences before and after long-term driving. Driving mental fatigue also impacts the function of the central nervous system, which consequently controls and regulates the cardiovascular system.

Wascher et al. (2014) wrote a research in order to track the cognitive and psychological changes that go along with time on task continuously. Fourteen people were participated in the experiment where the length of time of experiment is 4h, with 15 min breaks. In the experiment, there are two grey bars presented left and right from a fixation cross. Each of them was oriented either vertically or horizontally. Then, one of the two bars changed its colour, either to red or to blue. The subjects' task was to press a key based on the identity of the colour change. They pressed the left button for a change to blue and a right button for a change to red irrespective of the location of the colour change. The result showed that alpha power was larger at the end compared to the beginning of the experiment. However, alpha power increased rapidly and reached its maximal solitude already after 1h, whereas frontal theta showed a continuous increase with time on task. Thus, frontal theta turned out to be a reliable marker of distinct changes in cognitive processing with increase fatigue.

In summary, all of the inductive studies can be shorted as shown on Table 2.1 below.

Table 2.1 Previous Study of Research

No	Authors	Year	Title of Study	Object
1	Mun et al.	2014	Effect of mental fatigue caused by mobile 3D viewing on selective attention: an ERP study	Mental fatigue caused by mobile 3D viewing (entitled "The Call of the Wild", 2009) for approximately 80 min.
2	Chen et al.	2014	Assessment visual fatigue of watching 3DTV using EEG power spectral parameters	Mental fatigue of watching 3DTV and 2DTV versions of Ocean Wonderland
3	Chen et al.	2013	EEG -based detection and evaluation of fatigue caused by watching 3DTV	Mental fatigue of watching 3DTV and 2DTV
4	Charbonnier et al.	2016	EEG index for control operators mental fatigue monitoring using interactions between brain region	Mental fatigue of monitor operator
5	Boksem et al.	2006	Effect of mental fatigue attention: An ERP Study	Mental fatigue affects the attentional process
6	Arnau et al.	2017	The interconnection of mental fatigue and aging: An EEG study	The interconnection of mental fatigue and aging: An EEG study
7	Zhao et al.	2012	Electroencephalogram and electrocardiograph assessment of mental fatigue in a driving simulator	Driver’s mental fatigue
8	Wascher et al.	2014	Frontal theta activity reflects distinct aspect of mental fatigue	Mental fatigue on longer lasting performance in cognitively demanding tasks

Based on the previous study above, the measurement of mental fatigue using EEG assessment has been conducted by some researchers. However, mental fatigue measurement for high school student has not been conducted while student is on the Physics learning process in class.

2.7 LEARNING TYPE

In learning process, there is a regulatory process that refer to the kinds of overt and covert activities students perform during learning and to the decisions made about these activities. According to Simons (1989), there are 2 type of regulation; internal and external regulation. Internal regulation is regulation determined by the student him- or herself or called with autodidact learning regulation. Meanwhile, external regulation is regulation of learning determined by a teacher or called teacher regulation which, in this research, it is stated as non-autodidact learning regulation.

Autodidact learning type relates both to the number of these tasks students perform themselves and to their quality where an ideal autodidact learner chooses his/her own learning goal and tunes his/her learning activities to these goals in such a way that they are reached effectively and efficiently (Simons, 1989). Students personally initiate and direct their own efforts to acquire knowledge and skill rather than relying on teachers, parents, or other agents of instruction. Zimmerman (1989) stated that there is 3 importance elements of autodidact learning type which are student's autodidact learning strategies, self-efficacy perception of performance skill, and commitment to academic goals. Student's autodidact learning strategies are action and processes directed at gaining information include such methods as organizing and transforming information, seeking information, and rehearsing or using memory aids. Self-efficacy refers to perception of student about their capability to organize and implement action. Then, academic goals like grades, social esteem, or post-graduation employment opportunities.

Elsewhere, non-autodidact learning type or teacher regulated type is the presence of teacher on learning activities as an important role in stimulating and developing student (Van Beek et al., 2014). Non-autodidact has five main teaching tasks which are preparation of learning, facilitating learning, regulation of learning, feedback and judgement, and upholding student motivation and concentration (Simons, 1989).

CHAPTER III

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this chapter, it will be explained that the steps for conducting the research in order to keep researcher focused on the objective of this research. This chapter explains the detailed object and focus of research also the conceptual model of the research.

3.2 RESEARCH OBJECT

The object of this study is the mental fatigue of students that will face national examination especially science students when studying Physics. The objective measurement of mental fatigue is using electroencephalograph (EEG). EEG records the brain waves distinguished by their different frequency ranges which are alpha (α), theta (θ), and beta (β) (Sanei & Chambers, 2007). In accordance to the previous research, the amplitude of the alpha and theta rhythms significantly increased and the amplitude of the beta rhythm significantly decreased, while the mental fatigue level is increased (Babiloni, 2012).

3.3 RESEARCH SUBJECT

The subject of research is students in 3rd grade of senior high school in SMA N 1 Kasihan Bantul. The research has applied to 4 students. There are several requirements for the respondent, which are:

1. All respondents had no neurological and psychiatric mental problems that would affect performance (Wascher et al., 2014).
2. All respondents were instructed to abstain from cigarettes, caffeine, and alcohol for 12 hours before the experiment (Jaehne et al., 2012; Mun et al., 2014).
3. All respondents should have a full night's sleep for 6-8 hours before the experiment (Mun et al., 2014; National Sleep Foundation, 2008).
4. All respondents have similar interest on the Physics (Zhao et al., 2012).
5. All respondents are in motivated condition (Zimmerman, 1989).

Besides, the interest point and score of Physic subject should be identified to get a uniform background of research subject.

3.4 COLLECTING DATA METHOD

3.4.1 TYPE OF DATA

Primary data is data obtained directly from the research subject which conducted by experiment and direct measurement. The data that obtained in primary data is the electroencephalogram contain wave that will be processed and gaining about frequency, amplitude, and time of wave.

3.4.2 RESEARCH INSTRUMENT

Research instrument refers to the tools used in this study in order to collect or process the data. Instrument in this study include:

1. OpenBCI Ganglion Biosensing Board (4-channels) is used to record brain activity (EEG)
2. OpenBCI GUI 2.1.1 is a software tool for visualizing, recording, and streaming data from the OpenBCI Boards.
3. CSR 4.0 Bluetooth Dongle is a mini USB Bluetooth adapter to show EEG live
4. Gold cup electrode cables is a ribbon cable with 10 passive gold electrodes
5. Signa electrode gel sis a conductive liquid medium to detect the electrical activity under skin
6. Adhesive bandage as electrode paste to adhere the electrodes to the scalp
7. Alcohol as a cleaner for electrode before and after the experiment conducted
8. Table and chair as equipment for respondent sit when taking a part in the experiment
9. Physics book contains of subchapter that will be learned and some questions
10. Personal computer 13" used for presenting video on non-autodidact session
11. Sound Level meter is instruments capable for measuring the intensity of sound waves
12. Lux meter is an instrument that measures brightness
13. Thermometer is a device that measures temperature
14. Matlab R2016a is a software that is used for processing the EEG raw signal
15. IBM SPSS Statistic 22 is a software that is used for statistical analysis

3.4.3 LOCATION

The research will be conducted at the Laboratory of Computer Science and Electronics, Computer Science and Electronics Department, Faculty of Mathematics and Natural Science, Gadjah Mada University, Yogyakarta.

3.4.4 EXPERIMENT DESIGN

During the experiment, each respondent sits in comfortable position on the seat that has been provided. Experiment uses two different learning methods which is reading book as autodidact learning method and watching video as non-autodidact learning method (Simons, 1989). Each learning method is performed on both different condition whereas Dunn et al., (2002) revealed that 47 percent of high school students were late morning and afternoon learners, 40 percent were early morning learners, and remain was early night owls learners. So that, this study takes late morning and afternoon as types of learning condition. Thus, experiment consists of 4 sessions and 1 trial each session that included as subject experiment and shown in Figure 3.1 below.

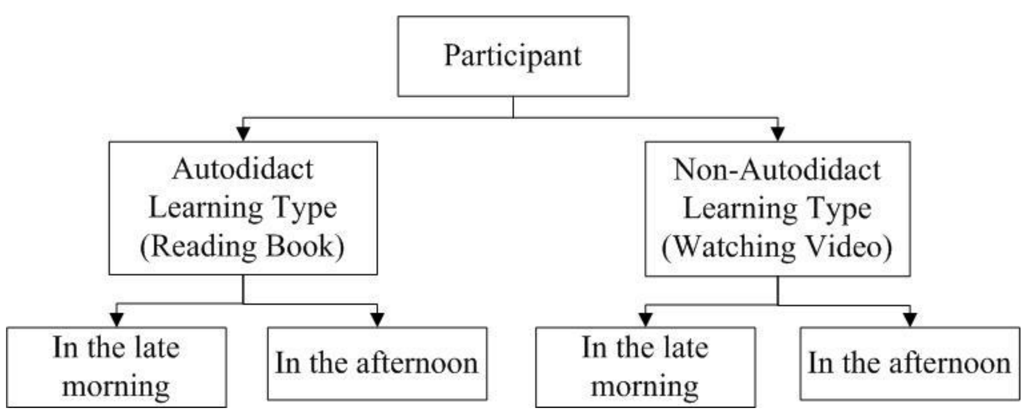


Figure 3.1 Experiment Design

Each experiment requires 5 minutes of briefing and getting used to be in a class, 90 minutes for studying, and 30 minutes for doing a test. The total experiment takes125 minutes per respondent for each learning tools. Time duration for studying is decided based on duration time of regular studying in school.

Experiment design in this research is treated the same way with work place setting on school, which respondent is occupied in layout shown in Figure 3.2 below.

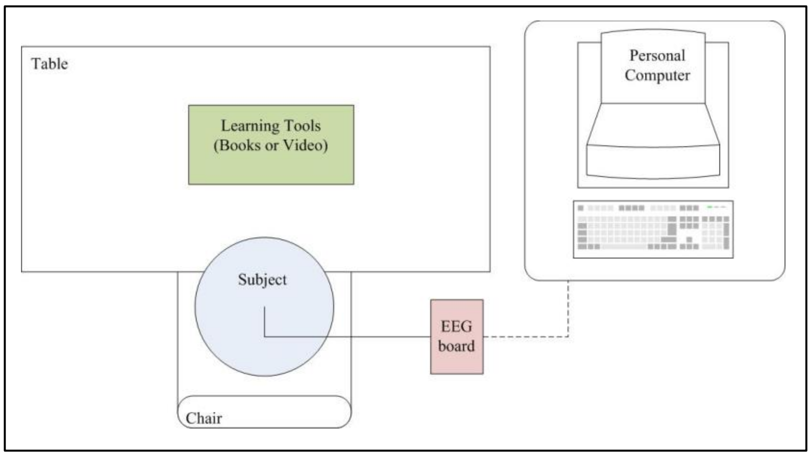


Figure 3.2 Experiment Layout

Four electrodes of Sn will be placed at frontal (F3 and F4) and Parietal (P3 and P4) according to the 10-20 system. Cheng & Hsu (2011) explained that the frontal lobes have been found to play a part in impulse control, judgment, language production, working memory, motor function, problem solving, sexual behavior, socialization, and spontaneity. Meanwhile, parietal lobe integrates sensory information, specifically dealing with spatial sense and navigation. Another function is comprehending numbers and the manipulation of objects. This area is responsible for sensation, or the ability of the brain to use senses to detect different environmental entities. Damage to this lobe can cause eyesight problems, left and right hemisphere confusion, inability to perform mathematical solutions, reading and writing problems, and symbol comprehension. Furthermore, (Babiloni, 2012) and Yin & Zhang (2017) stated that those electrodes (F3, F4, P3, and P4) have been commonly validated to analyse mental fatigue. The location of channel is shown in Figure 3.3 below.

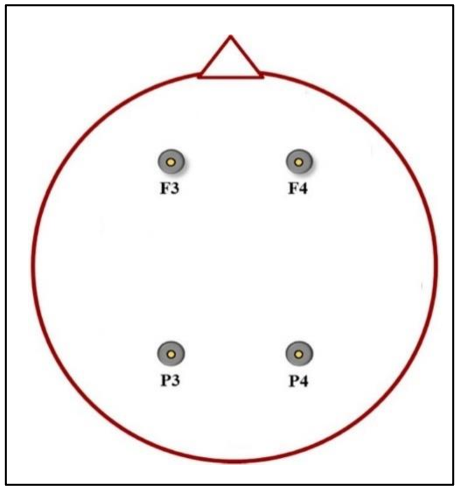


Figure 3.3 EEG Channel

3.4.5 TASK DESIGN

Experiment consists of 4 sessions and 1 trial for each session. In each session, respondent learns subchapter of Physics subject that is Electromagnetic Induction. This subchapter is the most difficult chapter among others (Hartanti T, personal communication, August 28, 2017). Babiloni (2012) expressed that the more demanding task, higher mental fatigue. Thus, this is reasonable to take this subchapter as task in this experiment.

The respondent is asked to learn Electromagnetic Induction in four different conditions which are autodidact learning method in the late morning, autodidact learning method in the afternoon, non-autodidact type in the late morning, and non-autodidact type in the afternoon. Autodidact learning method is the condition when respondent is self-taught by reading book that can be seen on Appendices 20. The book is taken from Physics book for class 3rd Senior High School by Handayani & Damari (2009). Meanwhile, non-autodidact type is the condition when respondent is watching video showing about someone is explaining the matter on blackboard by Sibejo (2016). Display of video is shown on Figure 3.4 below.

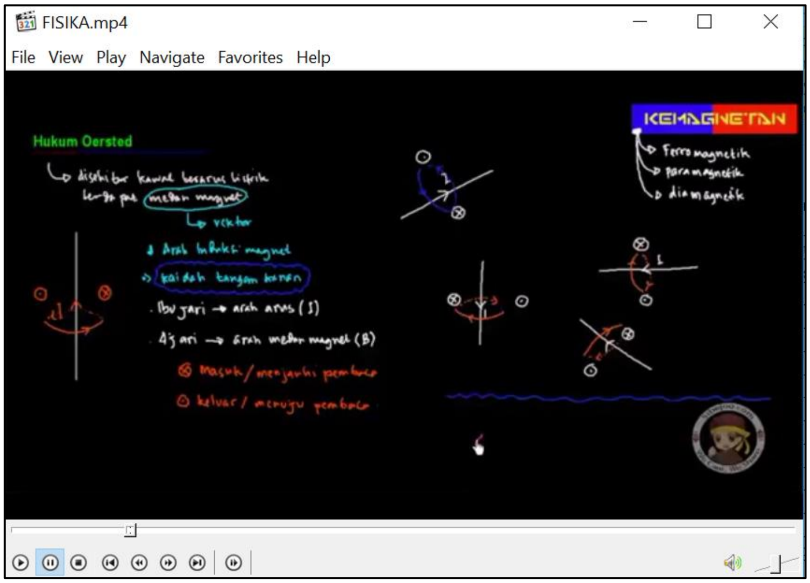


Figure 3.4 Display of Video
(Source: Sibejo, 2016)

At the same time, EEG tools is turned on to record brain activity on P3, P4, F3, and F4 when respondent learns Electromagnetic Induction for 90 minutes in each session. After it, respondent is asked to answer 10 questions related to the matter in 30 minutes that can be seen on Appendices 18 and Appendices 19.

3.4.6 EXPERIMENT PROCEDURE

The experiment is carried out for 2 days for each respondent because there are 4 sessions consist of 1 trial for each session. In the first day, at 8.55 in the late morning, respondent does first session by learning Physics using randomly learning method either autodidact or non-autodidact. It finishes until 11.00 and continued at 13.00 in the afternoon for second session. Respondent rests for 2 hours between late morning and afternoon session where based on Nishihara et al., (2014), mental fatigue can be recovered for stopping doing a task after 1 hour. Therefore, two hours rest is able to recover mental fatigue of respondents. In second session, respondent learns using different learning method compared to the previous one. In the next day, respondent does the third and fourth session on the same order as the previous day. The experiment timeline for each session can be seen in Figure 3.5 below.

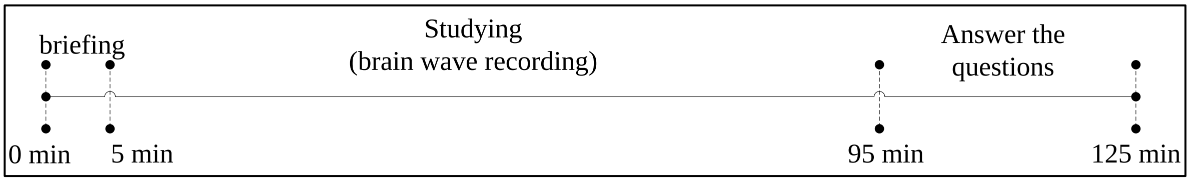


Figure 3.5 Experiment Timeline

Before doing the experiment, researcher prepares all the instruments also cleans the electrode with alcohol. Then, the order of experiment on each session could be resumed as follows:

1. Asking respondent to sit
2. Researcher finds the location of P3, P4, F3, and F4 on scalp.
3. Attaching electrode that has been given Signa electrode gel and uses adhesive bandage for adhering it. Electrodes are attached on P3, P4, F3, and F4 on scalp, and on both ears as ground.
4. Respondent is given a briefing and 5 minutes for getting used to be in a class and make sure that respondent has already been focused to study the Physics.
5. EEG is turned on for recording brain activity when respondent learns on first session.
6. Respondent learns subchapter Electromagnetic Induction using chosen learning method for 90 minutes.
7. EEG is turned off.
8. Remove the electrode from the scalp.
9. Respondent is asked to answer 10 questions for 30 minutes.
10. Respondent finishes first session of experiment.

3.5 DATA PROCESSING METHOD

Data processing method in this research is executed by reading the result experiment that recorded by Electroencephalograph with type OpenBCI Ganglion. Its signal interpretation was done using software OpenBCI GUI 2.1.1 in visualizing, recording, and streaming data. In recording brain activity, variable used in this study are learning method and condition.

Based on OpenBCI Ganglion type, there is a signal interference with a frequency of 50 Hz coming from electrical problems. Meanwhile, EEG signal frequency that is observed (theta, alpha, and beta) are in the range of 0 – 50 Hz. Related to this, two steps of processing are needed to be done which are Notch and Band Pass Filter. Notch filter is used to reject narrow frequency at 49-51 Hz to reject noise due to electrical problems and leaves the rest frequency. Band pass filter is used to select frequency from EEG data that will be used which is theta (4-8 Hz), alpha (8-13 Hz), and beta (13-30 Hz). Notch and band pass filter is processed using Matlab R2016a.

3.6 DATA ANALYSING METHOD

Data analysis is applied by employing signal analysis and non-parametric statistical analysis. Signal analysis is derived by calculating root mean square (RMS) of result after going through processing data. Beside it, Wilcoxon Signed Rank Test is done for identifying the difference between learning method and condition.

3.6.1 ROOT MEAN SQUARE CALCULATION

Electroencephalograph analysis is done by observing the signal that has been processed. It is done to find out on what seconds respondent will feel mental fatigue. A person can be said experiencing mental fatigue when alpha and theta rhythms of brain wave significantly increased, while the beta rhythm significantly decreased in amplitude (Babiloni, 2012; Wascher et al., 2014). In order to see the shift of amplitude easier, the RMS was calculated (Atmaji & Perwira, 2017; Soewardi et al., 2015). The formula of RMS is shown in Equation 3.1 below.

$$\bar{x_i} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} {x_i}^2} \qquad \ldots(3.1)$$

Where:

N = amount of data

X = value of data

3.6.2 STATISTICAL ANALYSIS

3.6.2.1 WILCOXON SIGNED-RANK TEST

The Wilcoxon signed-rank test is a nonparametric statistical hypothesis test used when comparing two related samples (Wilcoxon, 1946). In this study, this test is used to identify significance different of final score and early time for increasing Alpha and Theta data between autodidact and non-autodidact learning type, and also late morning and afternoon condition. The hypothesis used in this study is:

H_0 : there is no significant different between two related samples

H_1 : there is significant different between two related samples

If the significance value ≥ 0.05 the H_0 is accepted that means, there is no difference significantly. However, if the significance value < 0.05 then H_0 is rejected which means there is a significant difference between groups of samples.

The input for this statistical test is 4 data of final score and 4 data of early time for increasing Alpha and Theta in combination of learning type (autodidact and non-autodidact) and condition (late morning and afternoon). The output obtained is the difference value between autodidact learning type in both condition, non-autodidact learning type in both condition, late morning condition by both learning type, and afternoon condition by both learning type whether in significant or insignificant different.

3.7 CONCEPTUAL MODEL

The flowchart of the research is shown in Figure 3.6 below.

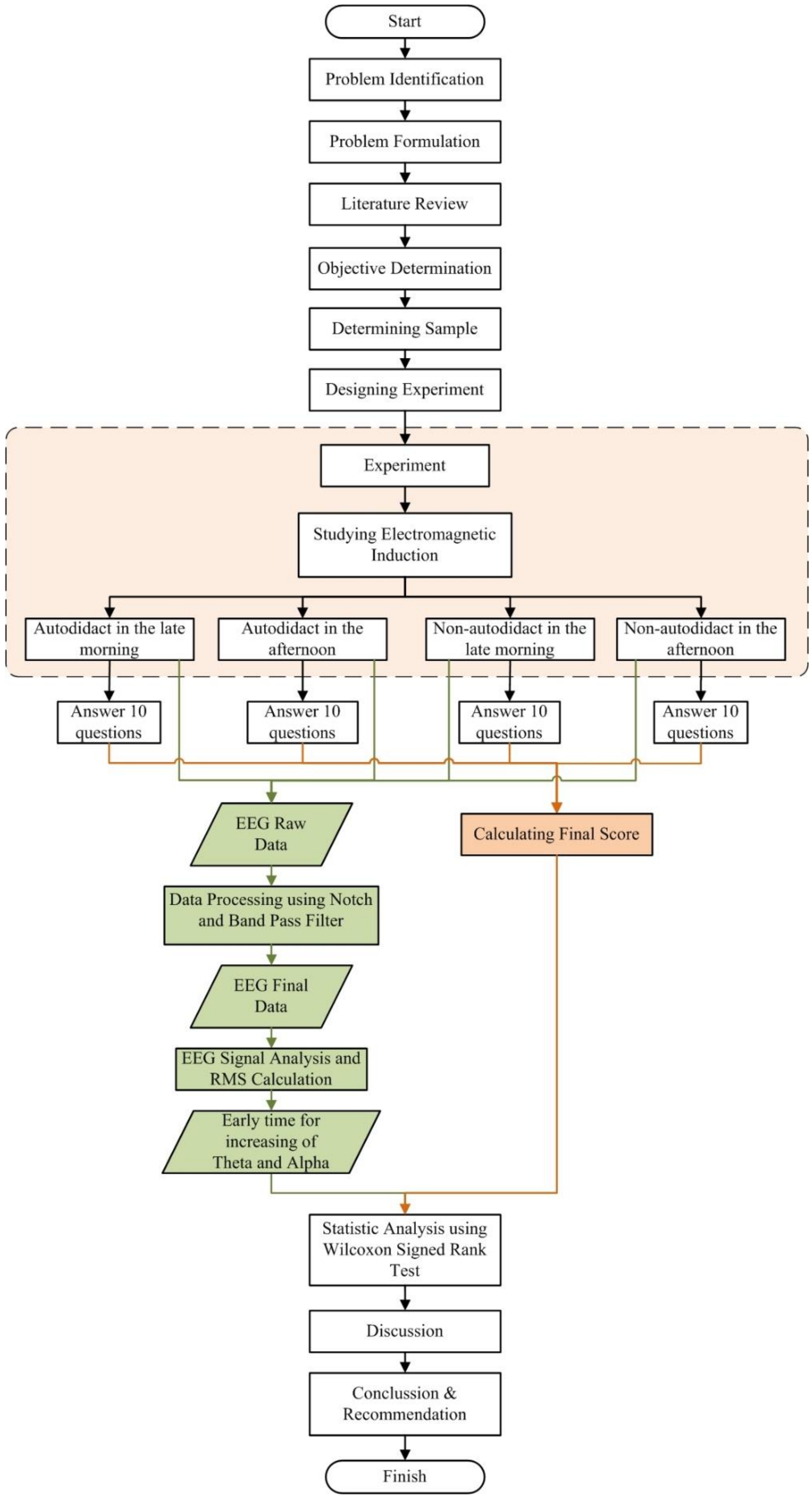


Figure 3.6 Research Flowchart

Based on Figure 3.6 above, it can be seen that the research is executed under several steps. It is started by identifying the problem and continued by formulating it. The fundamental problem on this research is average national examination's score of Physics in Bantul. Even the score for Physics subject in Bantul increased in 2017 while the score for Physics in Yogyakarta was always decreasing in last 3 years, the average score for Physics in Yogyakarta is still bigger than Bantul in each year. Then, it was known that mental fatigue student's factor has high effect in accomplishing a success. Literature study is done to carry out deeper about mental fatigue and the method to analyse it. Based on previous research, Electroencephalograph (EEG) is a sensitive tool in fluctuation of vigilance and has been shown mental fatigue that able to lowering performance. It is continued by determining the objective of research.The objective is the comparative of student's mental fatigue level while studying the Physics using book and video in the late morning and afternoon.

Henceforth, the next step is determining the sample and designing the experiment. Experiment consists of 4 sessions and 1 trial each session which is autodidact in the late morning, autodidact in the afternoon, non-autodidact in the late morning, and non-autodidact in the afternoon. The total experiment is 125 minutes per session. Respondents are asked to learn about subchapter of Physics subject that is Electromagnetic Induction. Four electrodes of Sn will be placed at frontal (F3 and F4) and Parietal (P3 and P4) according to the 10-20 system. Open BCI Ganglion Biosensing Board (4-channels) is used to record brain activity (EEG). Then, the experiment is done toward 4 students as respondents. Answering 10 question after each session is obligation.

Moreover, the raw data is processed using Notch and Bandpass by Matlab to get desired final data. Final data is analysed by calculating Root Mean Square (RMS). RMS is done in order to know the early time for amplitude shifting of Theta, Alpha, and Beta.

Wilcoxon Signed Rank Test is done as non-parametric statistic to demonstrate the difference between two related samples of the study. It uses to know the difference of final score and early time for increasing Theta and Alpha between different learning methods and conditions.

Furthermore, researcher analyses based on data processed which is the result of non-parametric statistic. Finally, researcher can conclude and provide recommendation based on the analysing data processed.

CHAPTER IV

DATA COLLECTING AND PROCESSING

4.1 DATA COLLECTION

The data collection on this research is about respondent's profile, raw data of EEG signals, and final score of study based on 10 questions offered.

4.1.1 RESPONDENT PROFILE

The respondent's profile was measured by direct measurement. Four students have been participated as described in Table 4.1 below

Table 4.1 Respondent Profile

Respondent	Age (years old)	Gender	Interest on Physics	Physics Score	Neurological problems	Psychiatric Mental Problems
1	17	Male	Like	80	-	-
2	17	Male	Like	84	-	-
3	18	Female	Like	82	-	-
4	17	Female	Like	80	-	-

Based on data collection, there were 4 students participated in this study in the range age of 17 to 18 years old. The interest point and score of Physic subject has been identified to get a uniform background of research subject. They liked physics subject which their physics score was above minimum completeness criteria score set by school (68) which is in range 80 to 84. Then, all respondents had no neurological and psychiatric mental problems, had no experience in smoking, abstained from caffeine for 12 hours, had a full night's sleep before the experiment, and like the Physics subject.

Respondent 1 and 3 learn the Physics by autodidact in the late morning for the first session of experiment day, non-autodidact in the afternoon for the second session, non-autodidact in the late morning for the third session, and autodidact in the afternoon for the last session. Meanwhile, respondent 2 and 4 learn the Physics by non-autodidact in the late morning for the first session of experiment day, autodidact in the afternoon for the second session, autodidact in the late morning for the third session, and non-autodidact in the afternoon for the last session.

4.1.2 EEG SIGNAL INTEPRETATION

EEG signal interpretation was done using software OpenBCI GUI 2.1.1 and Matlab R2016a. Software OpenBCI GUI 2.1.1 was used in visualizing, recording, and streaming data. It is shown in Figure 4.1 below.

Figure 4.1 Display of OpenBCI GUI 2.1.1

Meanwhile Matlab 2016 was used in processing the data and visualizing full time EEG raw data, full time EEG final data, precise time EEG final data, and calculating RMS.

In recording brain activity, variable used in this study is learning method and condition which were autodidact in the late morning, autodidact in the afternoon, non-autodidact in the late morning, and non-autodidact in the afternoon. Four electrodes of Sn were placed at F3, F4, P3, and P4. It was recorded whereas reference electrode was placed at the right and left ear lobes. Moreover, the sampling frequency was kept at 200 Hz and the skin impedance was below 19 kΩ stated as low impedance. Li et al., (2016) revealed that magnitude and stability of the electrode-skin impedance determines the quality of EEG signals. Low and stable electrode-skin impedance can minimize the impedance mismatch, which helps to reduce the powerline interference.

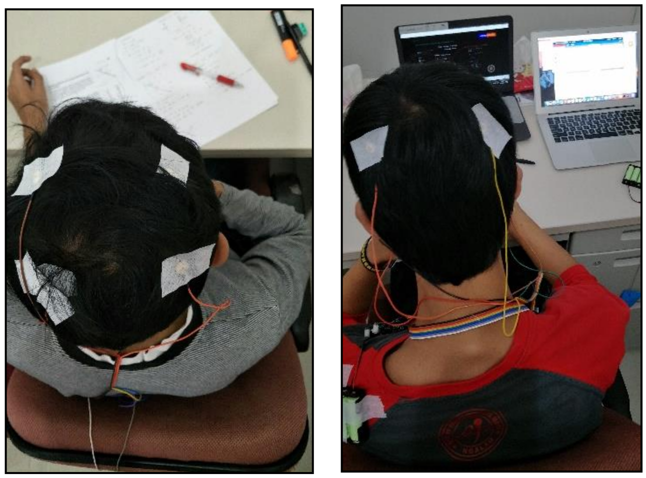


Figure 4.2 Brain Wave Recording Using Electroencephalograph

4.1.3 EEG RAW SIGNAL

EEG raw data is EEG signal recorded during experiment by OpenBCI GUI 2.1.1 without any signal process. It had some noise or unwanted signal by system. Those were EEG raw signal recorded on 4 session which were autodidact in the late morning, autodidact in the afternoon, non-autodidact in the late morning, and non-autodidact in the afternoon.

4.1.3.1 EEG Raw Signal of Autodidact in the Late Morning

First session of experiment was autodidact in the late morning session. It was conducted at 09.00 where respondent was asked to read sub-chapter of Physics (Electromagnetic Induction) as autodidact learning method. One of the raw brain wave recorded by EEG for 90 minutes in this session are shown in Figure 4.3 below.

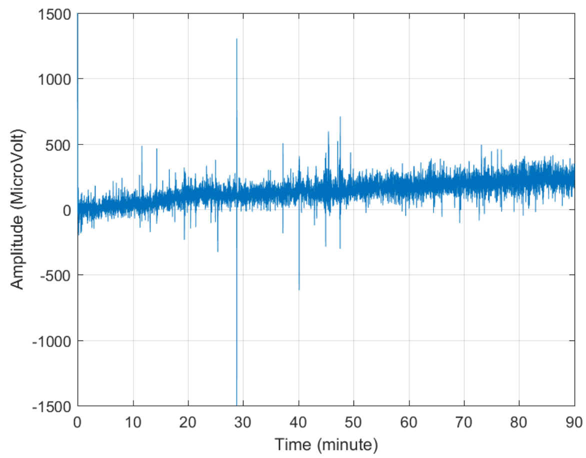


Figure 4.3 Raw Signal of Autodidact in the Late Morning

4.1.3.2 EEG Raw Signal of Autodidact in the Afternoon

Second session of experiment was autodidact in the afternoon session. It was conducted at 13.00 where respondent was asked to read sub-chapter of Physics (Electromagnetic Induction) as autodidact learning method. One of the raw brain wave recorded by EEG for 90 minutes in this session are shown in Figure 4.4 below.

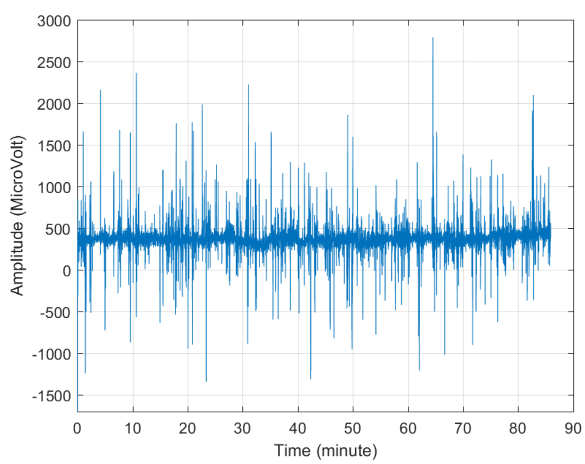


Figure 4.4 Raw Signal of Autodidact in the Afternoon

4.1.3.3 EEG Raw Signal of Non-Autodidact in the Late Morning

Third session of experiment was non-autodidact in the late morning session. It was conducted at 09.00 where respondent was asked to watch a video showing someone explains sub-chapter of Physics (Electromagnetic Induction) on blackboard as non-autodidact learning method. One of the raw brain wave recorded by EEG for 90 minutes in this session are shown in Figure 4.5 below.

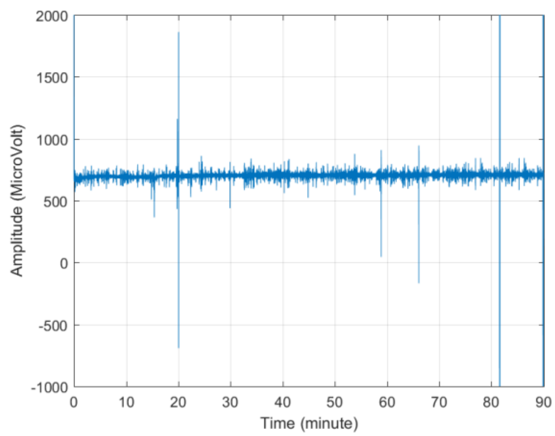


Figure 4.5 Raw Signal of Non-Autodidact in the Late Morning

4.1.3.4 EEG Raw Signal of Non-Autodidact in the Afternoon

Fourth session of experiment was non-autodidact in the afternoon session. It was conducted at 13.00 where respondent was asked to watch a video showing someone explains sub-chapter of Physics (Electromagnetic Induction) on blackboard as non-autodidact learning method. One of the raw brain wave recorded by EEG for 90 minutes in this session are shown in Figure 4.6 below.

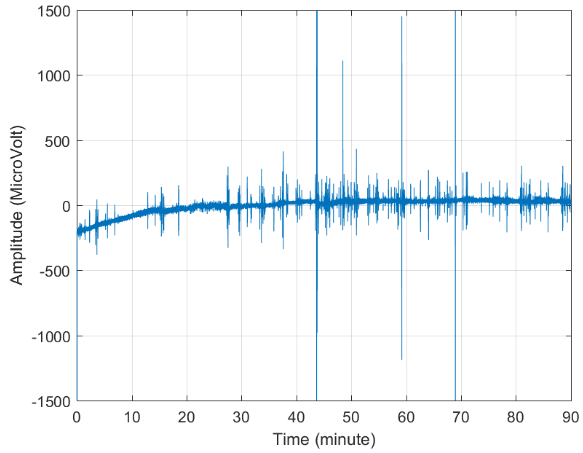


Figure 4.6 Raw Signal of Non-Autodidact in the Afternoon

4.1.4 SCORE OF STUDY

Score of study was gotten based on the correct answer toward 10 question. Table 4.2 below shows the score of Physic subject especially on Electromagnetic Induction subchapter by using two methods and different conditions in teaching learning process.

Table 4.2 Result of Score

Respondent	**Autodidact**		**Non-autodidact**	
	Late Morning	**Afternoon**	**Late Morning**	**Afternoon**
S1	60	50	30	20
S2	80	70	70	70
S3	60	50	60	30
S4	70	40	50	40
Average	67.5	52.5	52.5	40

4.2 DATA PROCESSING

The data that would be processed which is EEG raw data. It was processed using Notch and Bandpass by Matlab R2016a to get desired final data. The calculation of RMS should be done by seeing Theta, Alpha, and Beta of each channel to get early time of respondent for getting mental fatigue. Wilcoxon Signed Rank test was done as non-parametric statistic.

4.2.1 EEG FINAL SIGNAL

Notch filter was used to reject narrow frequency at 49-51 Hz for rejecting noise due to electrical problems and leaves the rest frequency. Band pass filter was used to select frequency from EEG data that would be used which is theta (4-8 Hz), alpha (8-13 Hz), and beta (13-30 Hz). Notch and band pass filter is processed using Matlab R2016a.

4.2.1.1 Theta

Theta waves lie within the range of 4 – 8 Hz. Theta waves appear as consciousness slips toward drowsiness (Sanei & Chambers, 2007). One of the final brain wave on lower frequency (theta) that had been processed through notch and band pass filter are shown in Figure 4.7 below.

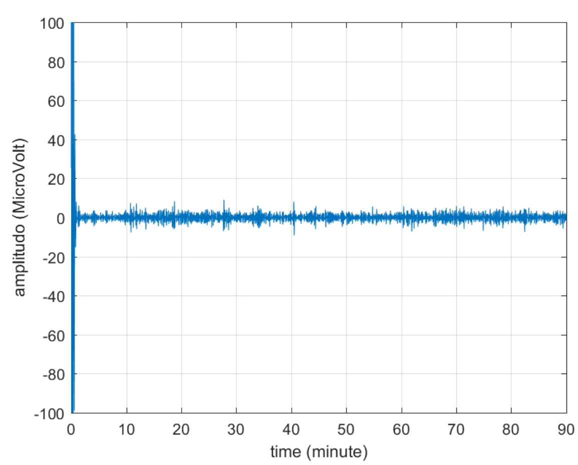


Figure 4.7 Final Signal of EEG on Theta Wave

4.2.1.2 Alpha

Alpha waves have frequency within the range of 8-13 Hz. It has been thought to indicate both a relaxed awareness without any attention or concentration. (Sanei & Chambers, 2007). One of the final brain wave on middle frequency (alpha) that had been processed through notch and band pass filter are shown in Figure 4.8 below.

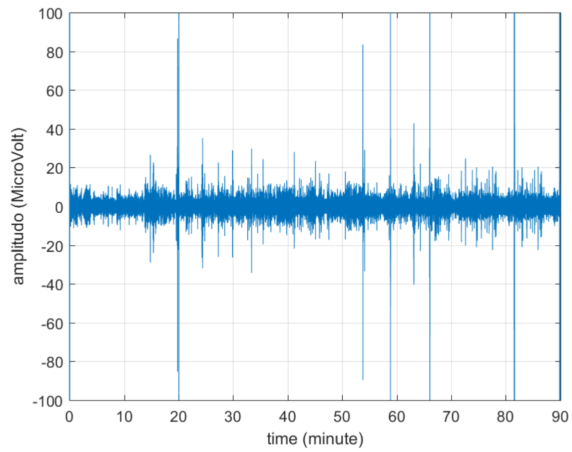


Figure 4.8 Final Signal of EEG on Alpha Wave

4.2.1.3 Beta

A beta waves is the electrical activity of the brain varying within the range of 13-30 Hz. A beta wave is the usual waking rhythm of the brain associated with active thinking, active attention, focus on the outside world, or solving concrete problems (Sanei & Chambers, 2007). One of the final brain wave on higher frequency (beta) that had been processed through notch and band pass filter are shown in Figure 4.9 below.

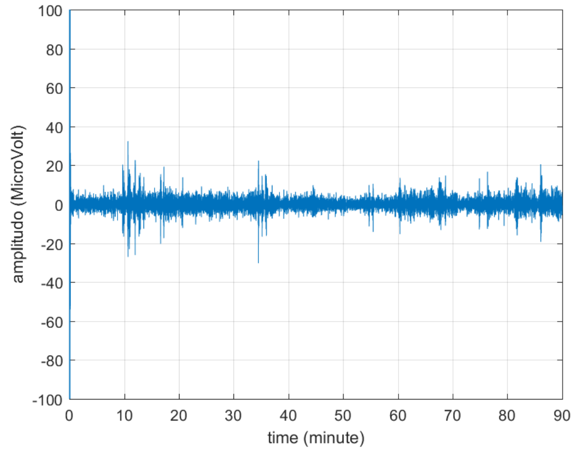


Figure 4.9 Final Signal of EEG on Beta Wave

4.2.2 RMS CALCULATION

Calculation of RMS was done using formula on equation 3.1 that is used on final signal of EEG on each wave for every channels and sessions. It was used in order to see the shift of amplitude on Theta, Alpha, and Beta wave.

4.2.2.1 Autodidact in the Late Morning

a. Respondent 1

Figure 4.10 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the late morning at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha at the 49th minute, where the value of Beta, Theta, and Alpha was 9.8041, 6.1997, and 7.1509 µv at the 49th minute. Then, the amplitude of Theta (9.3048 µv) at 50th minute increased and was always greater than amplitude of Alpha (6.1748 µv) and Beta (7.4560 µv).

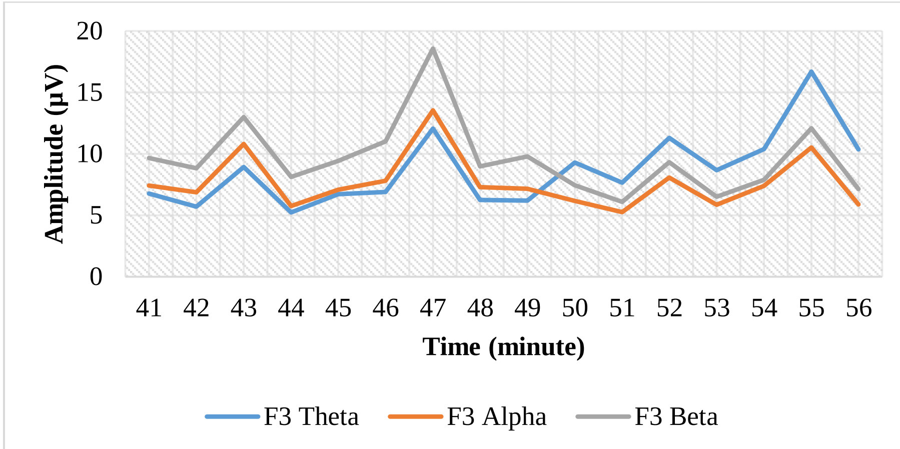


Figure 4.10 RMS Graphic on Respondent 1 at F3 by autodidact in the late morning

Figure 4.11 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the late morning at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at 49th minute, where the value of Beta, Theta, and Alpha was 7.2753, 4.5984, and 4.9640 µv at 49th minute. Then, the amplitude of Theta (7.1210 µv) at the 50th minute increased and was always greater than amplitude of Alpha (4.7321 µv) and Beta (5.0803 µv).

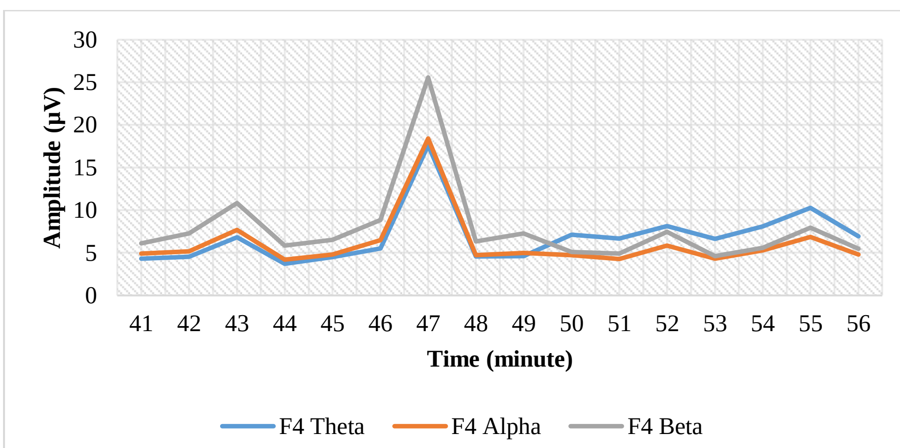


Figure 4.11 RMS Graphic on Respondent 1 at F4 by autodidact in the late morning

Figure 4.12 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the late morning at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 49th minute, where the value of Beta, Theta, and Alpha was 10.4770, 7.0459, and 7.5706 µv at the 49th minute. Then, the amplitude of Theta (9.5060 µv) at the 50th minute increased and was always greater than amplitude of Alpha (6.1465 µv) and Beta (6.8946 µv).

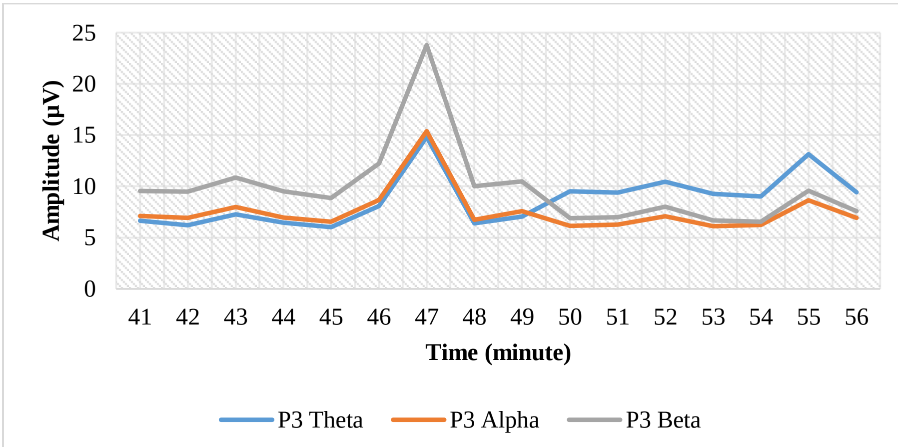


Figure 4.12 RMS Graphic on Respondent 1 at P3 by autodidact in the late morning

Figure 4.13 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the late morning at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 49th minute, where the value of Beta, Theta, and Alpha was 11.3584, 7.3836, and 7.9585 µv at the 49th minute. Then, the amplitude of Theta (10.8446 µv) at the 50th minute increased and was always greater than amplitude of Alpha (6.8895 µv) and Beta (8.0442 µv).

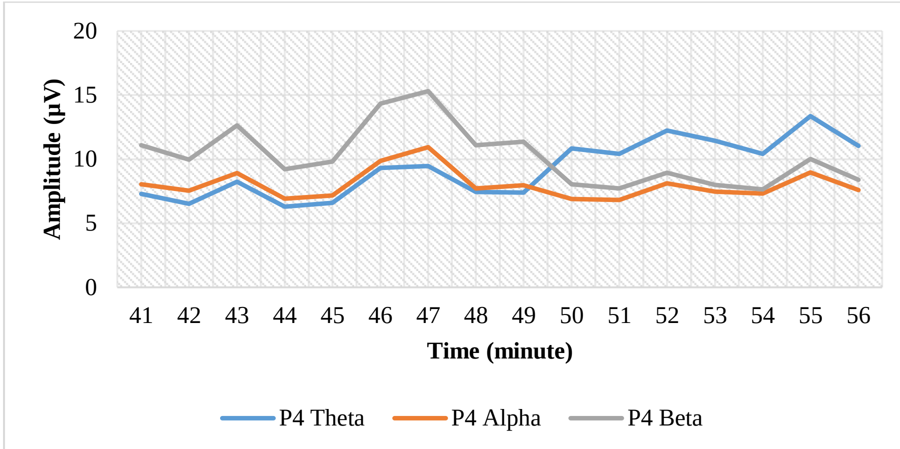


Figure 4.13 RMS Graphic on Respondent 1 at P4 by autodidact in the late morning

Based on Figure 4.10 and Figure 4.11, the ability of respondent 1 to memorize and solve problems appeared until at the 49th minute. Then at the 50th minute, it decreased and respondent 1 felt sleepy. As well as shown on Figure 4.12 andFigure 4.13, the ability of respondent 1 to read and understand the lesson appeared until at the 49th minute. Then at the 50th minute, it decreased and respondent 1 felt sleepy. It indicated that respondent 1 had not focussed on Physics subject at the 50th minute during studying on autodidact in the late morning.

b. Respondent 2

Figure 4.14 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the late morning at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 47th minute, where the value of Beta, Theta, and Alpha was 6.4773, 4.7371, and 4.7020 µv at the 47th minute. Then, the amplitude of Theta (23.3589 µv) at the 48th minute increased and was greater than amplitude of Alpha (15.8789 µv) and Beta (16.1328 µv).

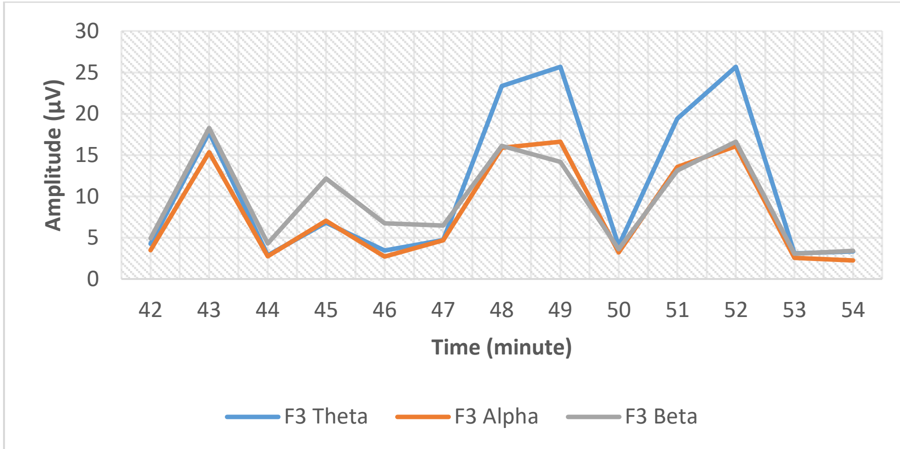


Figure 4.14 RMS Graphic on Respondent 2 at F3 by autodidact in the late morning

Figure 4.15 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the late morning at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 47th minute, where the value of Beta, Theta, and Alpha was 6.2958, 5.2052, and 5.0360 µv at the 47th minute. Then, the amplitude of Theta (19.0338 µv) at the 48th minute increased and was greater than amplitude of Alpha (14.1183 µv) and Beta (14.8774 µv).

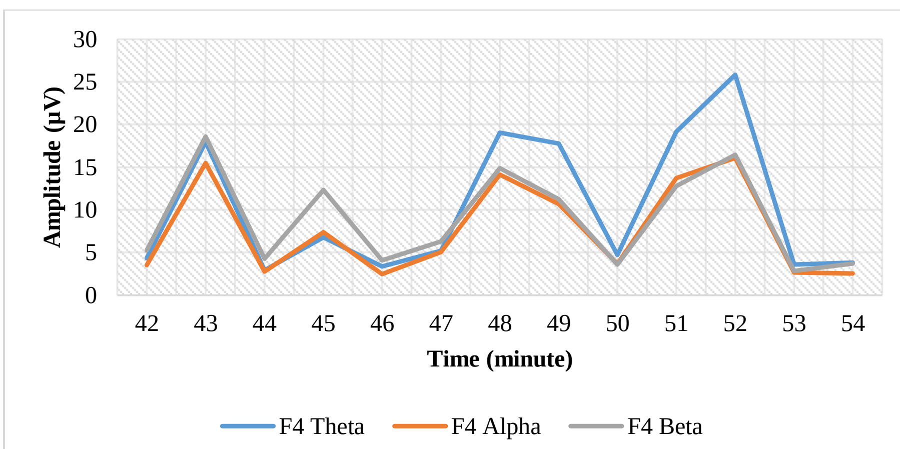


Figure 4.15 RMS Graphic on Respondent 2 at F4 by autodidact in the late morning

Figure 4.16 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the late morning at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 47th minute, where the value of Beta, Theta, and Alpha was 6.3741, 4.4054, and 5.0326 µv at the 47th minute. Then, the amplitude of Theta (18.9129 µv) at the 48th minute increased and was greater than amplitude of Alpha (14.1392 µv) and Beta (14.9572 µv).

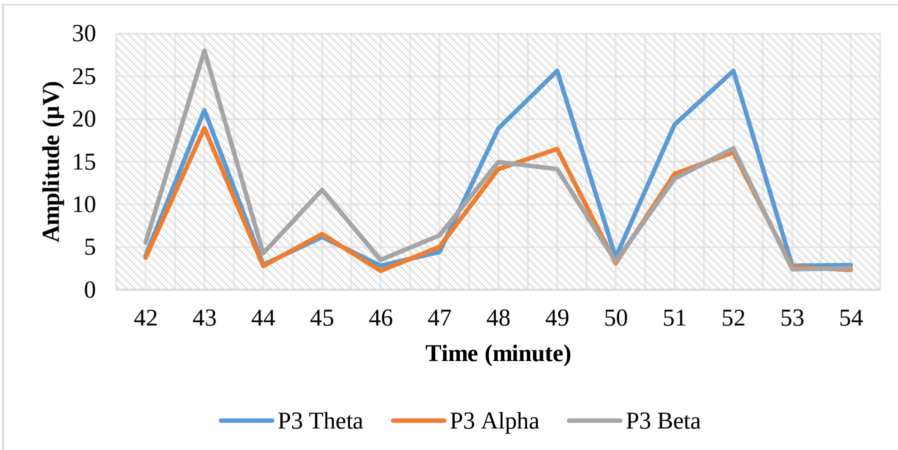


Figure 4.16 RMS Graphic on Respondent 2 at P3 by autodidact in the late morning

Figure 4.17 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the late morning at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 47th minute, where the value of Beta, Theta, and Alpha was 6.4194, 4.8581, 5.2492 µv at the 47th minute. Then, the amplitude of Theta (23.3340 µv) at the 48th minute increased and was greater than amplitude of Alpha (15.8709 µv) and Beta (16.0710 µv).

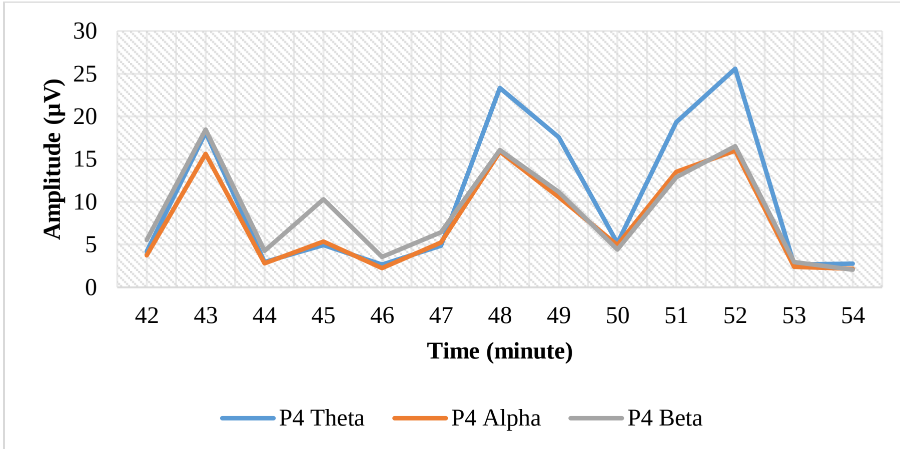


Figure 4.17 RMS Graphic on Respondent 2 at P4 by autodidact in the late morning

Based on Figure 4.14 and Figure 4.15, the ability of respondent 2 to memorize and solve problems appeared until at the 47th minute. Then at the 48th minute, it decreased and respondent 2 felt sleepy. As well as shown on Figure 4.16 and Figure 4.17, the ability of respondent 2 to read and understand the lesson appeared until at the 47th minute. Then at the 48th minute, it decreased and respondent 2 felt sleepy. It indicated that respondent 2 had not focussed on Physics subject at the 48th minute during studying on autodidact in the late morning.

c. Respondent 3

Figure 4.18 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the late morning at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 60th minute, where the value of Beta, Theta, and Alpha was 5.4165, 3.9254, and 4.1439 µv at the 60th minute. Then, the amplitude of Theta (12.7279 µv) at the 61st minute increased and was always greater than amplitude of Alpha (9.4935 µv) and Beta (9.3499 µv).

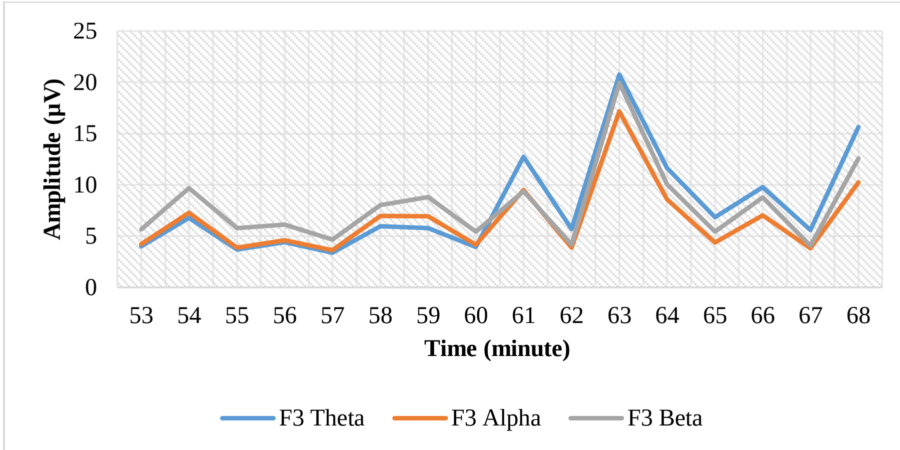


Figure 4.18 RMS Graphic on Respondent 3 at F3 by autodidact in the late morning

Figure 4.19 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the late morning at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 60th minute, where the value of Beta, Theta, and Alpha was 6.2417, 4.5828, and 4.5879 µv at the 60th minute. Then, the amplitude of Theta (8.0840 µv) at the 61st minute increased and was always greater than amplitude of Alpha (6.1066 µv) and Beta (6.4558 µv).

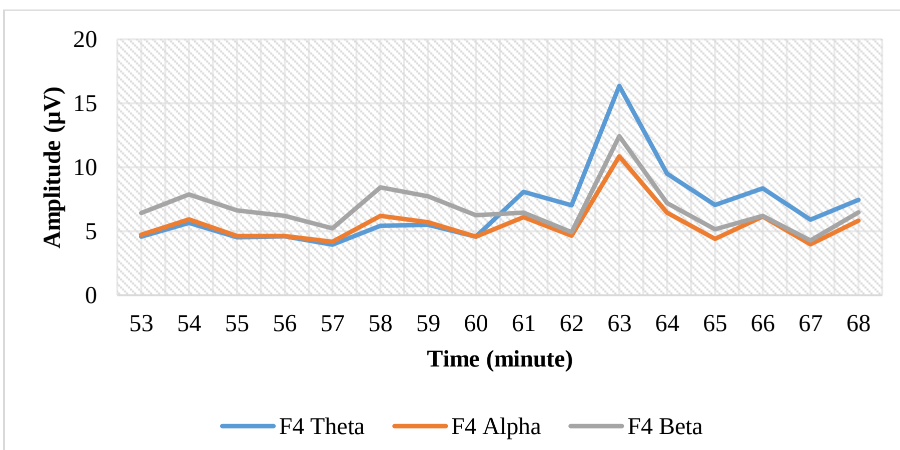


Figure 4.19 RMS Graphic on Respondent 3 at F4 by autodidact in the late morning

Figure 4.20 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the late morning at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 60th minute, where the value of Beta, Theta, and Alpha was 6.9863, 4.6606, and 5.1101 µv at the 60th minute. Then, the amplitude of Theta (7.2938 µv) at the 61st minute increased and was always greater than amplitude of Alpha (5.1226 µv) and Beta (5.6448 µv).

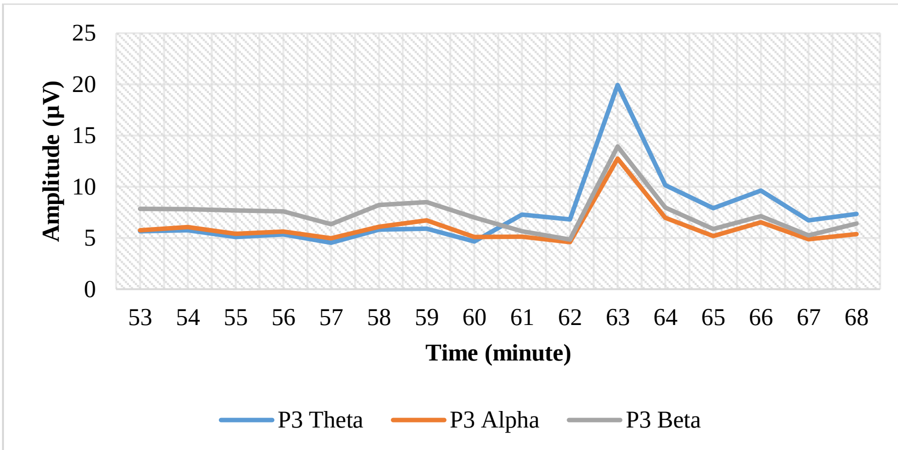


Figure 4.20 RMS Graphic on Respondent 3 at P3 by autodidact in the late morning

Figure 4.21 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the late morning at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 60th minute, where the value of Beta, Theta, and Alpha was 7.4726, 5.4912, and 5.7120 µv at the 60th minute. Then, the amplitude of Theta (8.4547 µv) at the 61st minute increased and was always greater than amplitude of Alpha (6.1470 µv) and Beta (6.5695 µv).

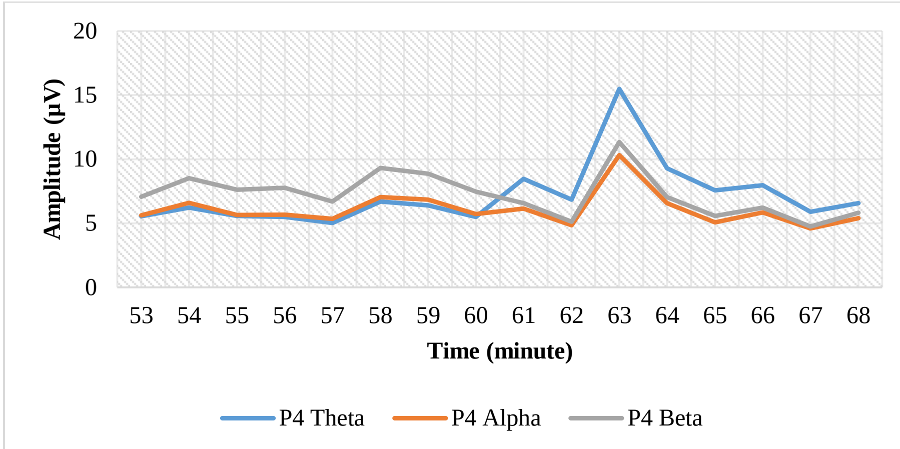


Figure 4.21 RMS Graphic on Respondent 3 at P4 by autodidact in the late morning

Based on Figure 4.18 and Figure 4.19, the ability of respondent 3 to memorize and solve problems appeared until at the 60th minute. Then at the 61st minute, it decreased and respondent 3 felt sleepy. As well as shown on Figure 4.20 and Figure 4.21, the ability of respondent 3 to read and understand the lesson appeared until at the 60th minute. Then at the 61st minute, it decreased and respondent 3 felt sleepy. It indicated that respondent 3 had not focussed on Physics subject at the 61st minute during studying on autodidact in the late morning.

d. Respondent 4

Figure 4.22 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the late morning at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 57th minute, where the value of Beta, Theta, and Alpha was 6.0242, 4.2019, and 5.0901 µv at the 57th minute. Then, the amplitude of Theta (7.2003 µv) at the 58th minute increased and was greater than amplitude of Alpha (5.0558 µv) and Beta (5.6945 µv).

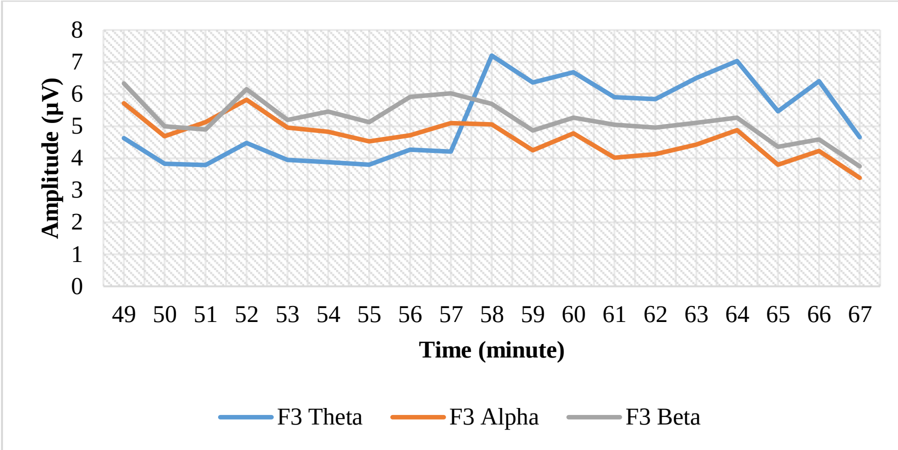


Figure 4.22 RMS Graphic on Respondent 4 at F3 by autodidact in the late morning

Figure 4.23 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the late morning at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 57th minute, where the value of Beta, Theta, and Alpha was 6.6859, 4.6894, and 5.3609 µv at the 57th minute. Then, the amplitude of Theta (7.4391 µv) at the 58th minute increased and was greater than amplitude of Alpha (5.1884 µv) and Beta (5.6915 µv).

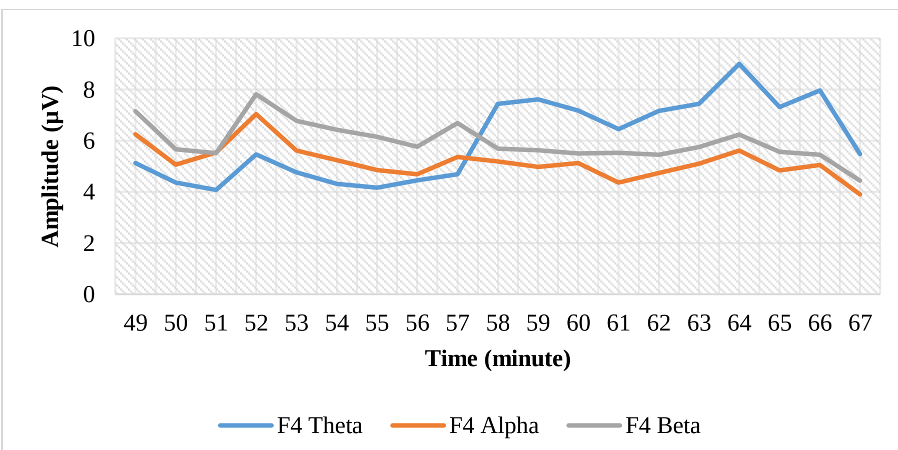


Figure 4.23 RMS Graphic on Respondent 4 at F4 by autodidact in the late morning

Figure 4.24 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the late morning at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 57th minute, where the value of Beta, Theta, and Alpha was 7.5910, 5.3047, and 6.2330 µv at the 57th minute. Then, the amplitude of Theta (8.5144 µv) at the 58th minute increased and was greater than amplitude of Alpha (6.2105 µv) and Beta (7.0553 µv).

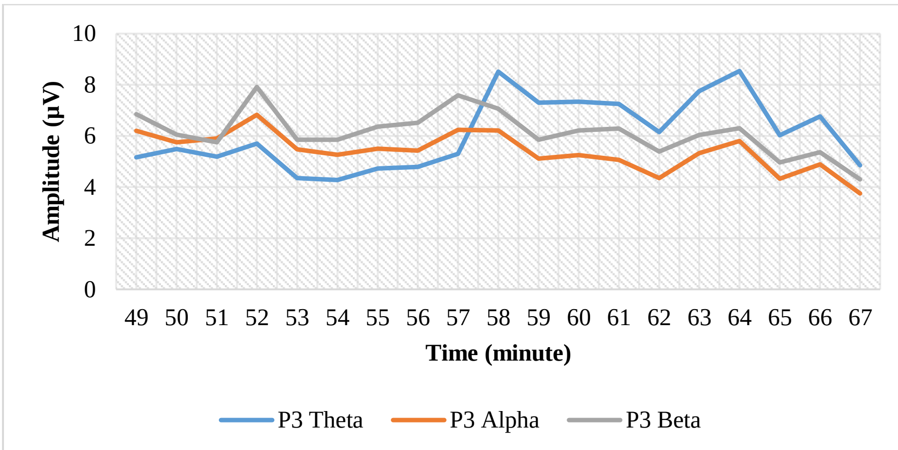


Figure 4.24 RMS Graphic on Respondent 4 at P3 by autodidact in the late morning

Figure 4.25 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the late morning at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 57th minute, where the value of Beta, Theta, and Alpha was 8.3547, 5.8612, and 6.7122 µv at the 57th minute. Then, the amplitude of Theta (8.5144 µv) at the 58th minute increased and was greater than amplitude of Alpha (6.2105 µv) and Beta (7.0553 µv).

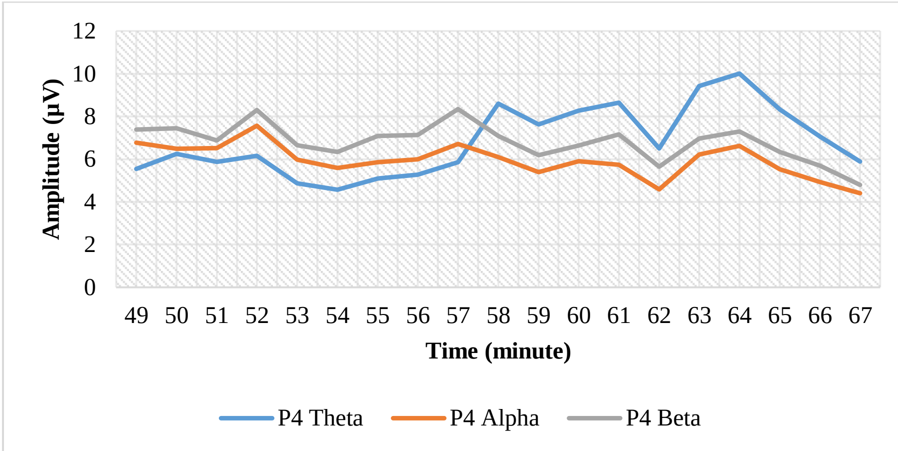


Figure 4.25 RMS Graphic on Respondent 4 at P4 by autodidact in the late morning

Based on Figure 4.22 and Figure 4.23, the ability of respondent 4 to memorize and solve problems appeared until at 57^{th} minute. Then at 58^{th} minute, it decreased and respondent 4 felt sleepy. As well as shown on Figure 4.24 and Figure 4.25, the ability of respondent 4 to read and understand the lesson appeared until at the 57^{th} minute. Then at the 58^{th} minute, it decreased and respondent 4 felt sleepy. It indicated that respondent 4 had not focussed on Physics subject at the 58^{th} minute during studying on autodidact in the late morning.

4.2.2.2 Autodidact in the Afternoon

a. Respondent 1

Figure 4.26 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 27^{th} minute, where the value of Beta, Theta, and Alpha was 8.7847, 4.2864, and 6.7219 µv at the 27^{th} minute. Then, the amplitude of Beta (2.3830 µv) at the 28^{th} minute decreased and the amplitude of Theta (3.0313 µv) was the highest. After at the 28^{th} minute, amplitude of Theta was fluctuated and reach the highest value (9.9867 µv) at the 34^{th} minute.

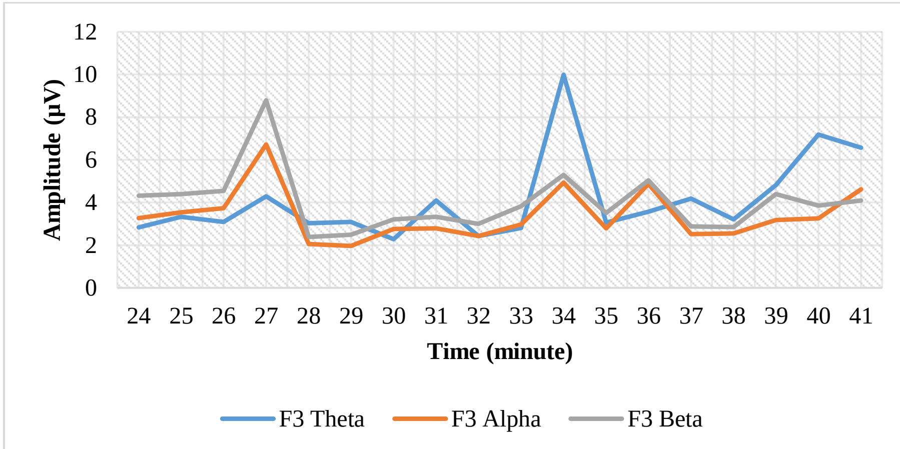


Figure 4.26 RMS Graphic on Respondent 1 at F3 by autodidact in the afternoon

Figure 4.27 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 29th minute, where the value of Beta, Theta, and Alpha was 3.6613, 3.0772, and 3.0198 µv at the 29th minute. Then, the amplitude of Theta (4.3081 µv) at the 30th minute increased and was greater than amplitude of Alpha (3.2684 µv) and Beta (3.2684 µv). After at the 30th minute, amplitude of Theta was fluctuated and reach the highest value (10.0617 µv) at the 34th minute. Meanwhile, after at the 36th minute, the amplitude of Alpha (5.7610 µv) was greater than amplitude of Theta (5.4538 µv) and Beta (4.6985 µv).

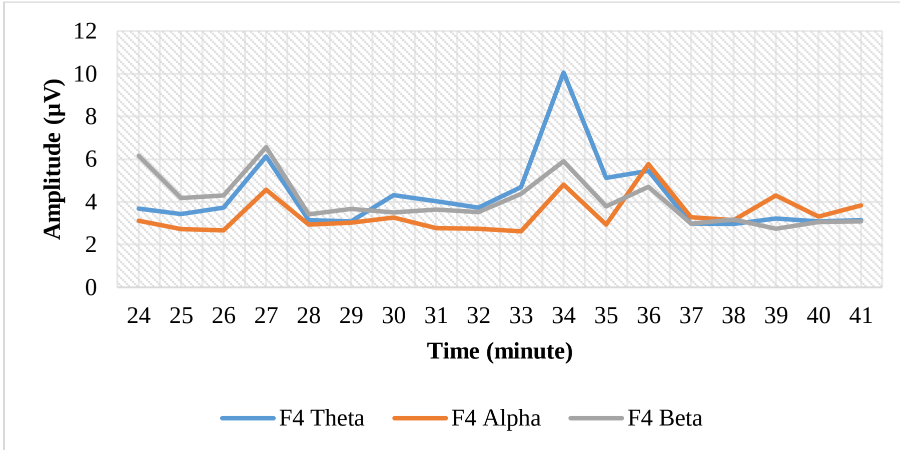


Figure 4.27 RMS Graphic on Respondent 1 at F4 by autodidact in the afternoon

Figure 4.28 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 28th minute, where the value of Beta, Theta, and Alpha was 3.6733, 3.4064, and 3.6389 µv at the 28th minute. Then, the amplitude of Theta (4.6204 µv) at 30th minute increased and was greater than amplitude of Alpha (4.2592 µv) and Beta (4.0673 µv). After at the 30th minute, amplitude of Theta was fluctuated and reach the highest value (10.0162 µv) at 34th minute. Meanwhile, after at the 37th minute, the amplitude of Alpha (4.7807 µv) was greater than amplitude of Theta (3.5030 µv) and Beta (4.3372 µv).

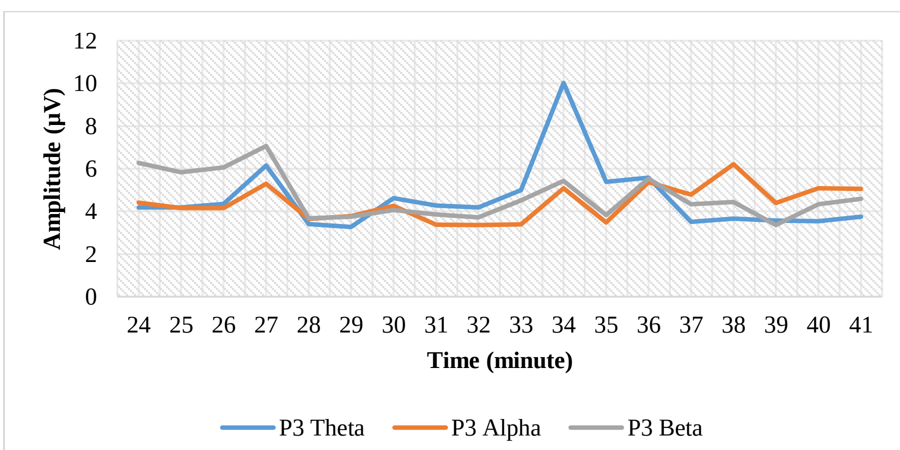


Figure 4.28 RMS Graphic on Respondent 1 at P3 by autodidact in the afternoon

Figure 4.29 shows the amplitude RMS graphic of first respondent's EEG final signal on autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 29th minute, where the value of Beta, Theta, and Alpha was 3.6287, 3.1757, and 3.3592 µv at the 29th minute. Then, the amplitude of Theta (4.9562 µv) at the 31st minute increased and was greater than amplitude of Alpha (3.3172 µv) and Beta (4.0678 µv). After at the 31st minute, amplitude of Theta was fluctuated and reach the highest value (9.8503 µv) at the 34th minute. Meanwhile, after at the 37th minute, the amplitude of Alpha (3.8849 µv) was greater than amplitude of Theta (2.9979 µv) and Beta (3.8801 µv).

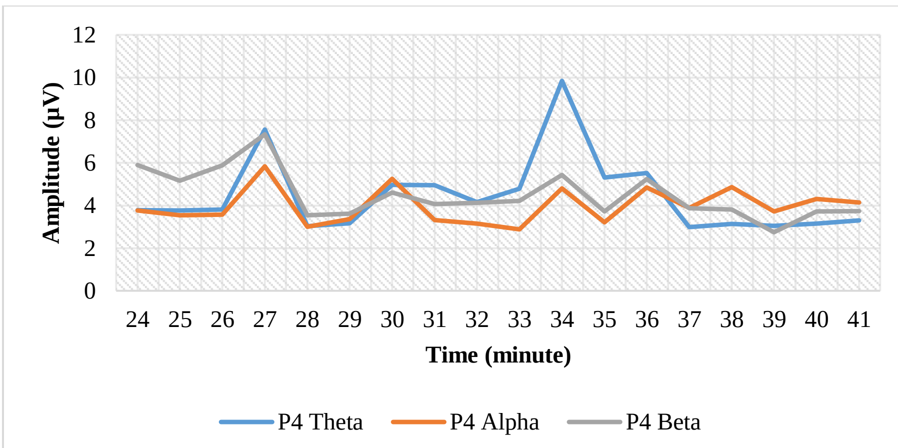


Figure 4.29 RMS Graphic on Respondent 1 at P4 by autodidact in the afternoon

Based on Figure 4.26 and Figure 4.27 the ability of respondent 1 to memorize and solve problems appeared until at the 33rd minute. Then at the 34th minute, it decreased and respondent 4 felt sleepy. As well as shown on Figure 4.28 and Figure 4.29, the ability of respondent 4 to read and understand the lesson appeared until at the 29th minute. Then at the 30th minute, it decreased and respondent 4 had no concentration and felt sleepy. It indicated that respondent 4 had not focussed on Physics subject at the 34th minute during studying on autodidact in the afternoon.

b. Respondent 2

Figure 4.30 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 30th minute, where the value of Beta, Theta, and Alpha was 26.0160, 15.8900, and 19.0639 µv at the 30th minute. Then, the amplitude of Theta (27.9968 µv) at the 31st minute increased and was always the greatest compare to amplitude of Alpha (19.5315 µv) and Beta (16.3449 µv).

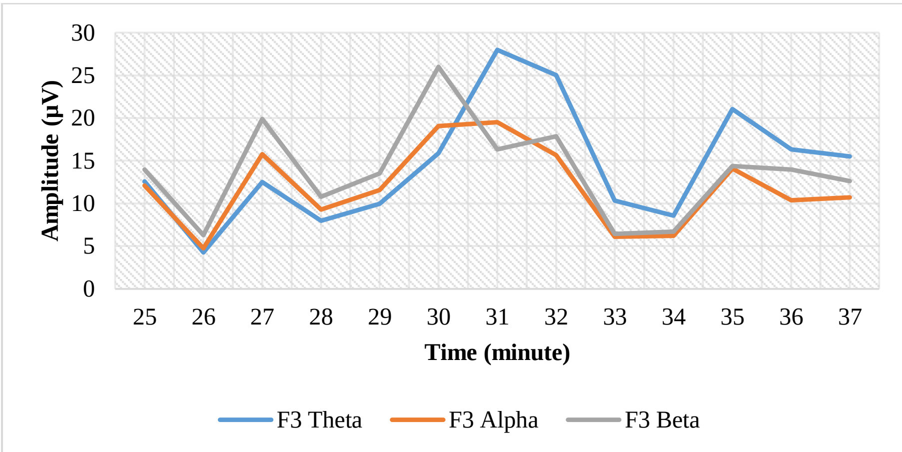


Figure 4.30 RMS Graphic on Respondent 2 at F3 by autodidact in the afternoon

Figure 4.31 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 30th minute, where the value of Beta, Theta, and Alpha was 16.5166, 10.0217, and 11.4230 µv at the 30th minute. Then, the amplitude of Theta (22.8917 µv) at the 31st minute increased and was always the greatest compare to amplitude of Alpha (17.9839 µv) and Beta (14.1968 µv).

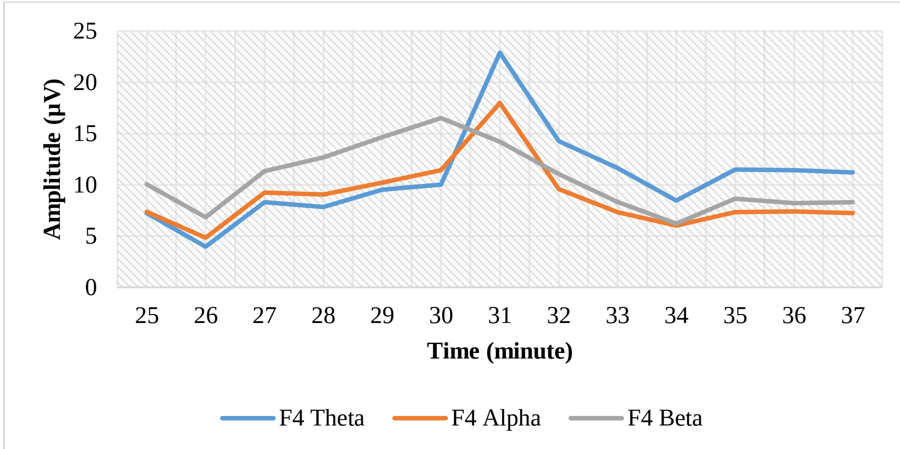


Figure 4.31 RMS Graphic on Respondent 2 at F4 by autodidact in the afternoon

Figure 4.32 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 30th minute, where the value of Beta, Theta, and Alpha was 17.5960, 11.4130, and 11.6926 µv at the 30th minute. Then, the amplitude of Theta (15.4722 µv) at the 31st minute increased and was always the greatest compare to amplitude of Alpha (12.1413 µv) and Beta (10.0723 µv).

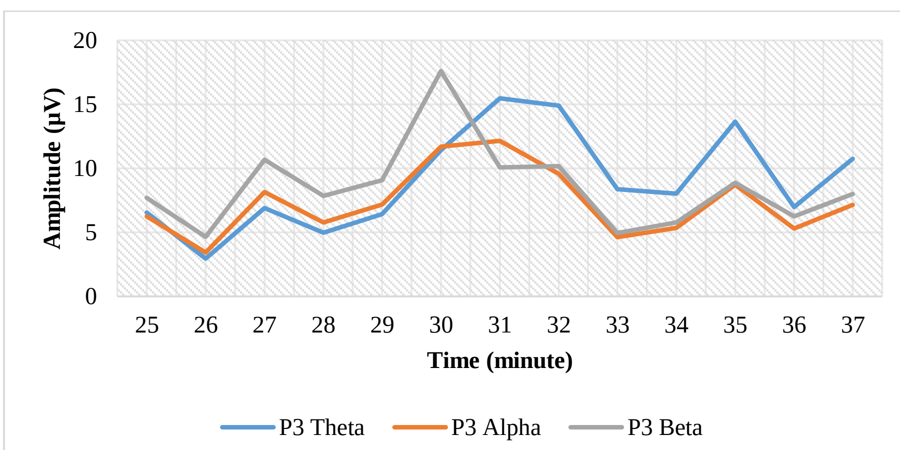


Figure 4.32 RMS Graphic on Respondent 2 at P3 by autodidact in the afternoon

Figure 4.33 shows the amplitude RMS graphic of second respondent's EEG final signal on autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 30th minute, where the value of Beta, Theta, and Alpha was 15.0935, 9.6349, and 10,5910 µv at the 30th minute. Then, the amplitude of Theta (14.4857 µv) at the 31st minute increased and was always the greatest compare to amplitude of Alpha (10.2969 µv) and Beta (9.0022 µv).

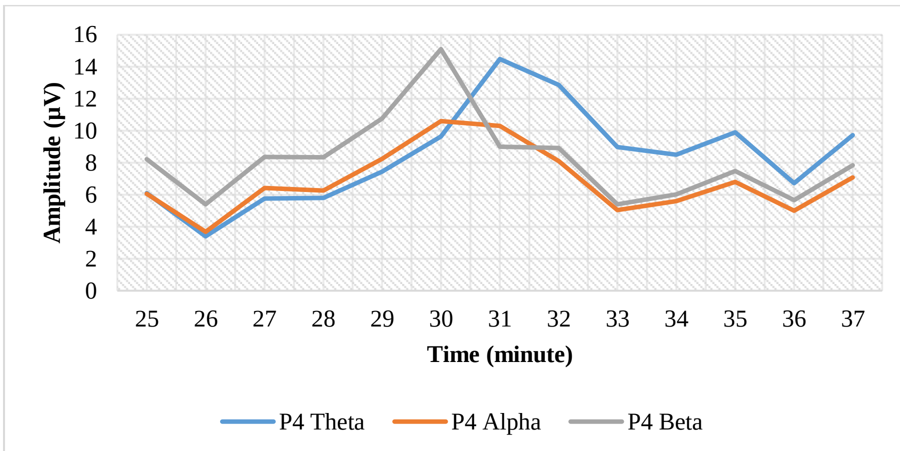


Figure 4.33 RMS Graphic on Respondent 2 at P4 by autodidact in the afternoon

Based on Figure 4.30 and Figure 4.31, the ability of respondent 2 to memorize and solve problems appeared until at the 30th minute. Then at the 31st minute, it decreased and respondent 2 felt sleepy. As well as shown on Figure 4.32 and Figure 4.33, the ability of respondent 2 to read and understand the lesson appeared until at the 30th minute. Then at the 31st minute, it decreased and respondent 4 felt sleepy. It indicated that respondent 2 had not focussed on Physics subject at the 31st minute during studying on autodidact in the afternoon.

c. Respondent 3

Figure 4.34 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 26th minute, where the value of Beta, Theta, and Alpha was 20.4273, 13.6089, and 19.5308 µv at the 26th minute. Then, the amplitude of Theta (17.6676 µv) at the 27th minute increased and was always the greatest compare to amplitude of Alpha (11.2063 µv) and Beta (11.7180 µv).

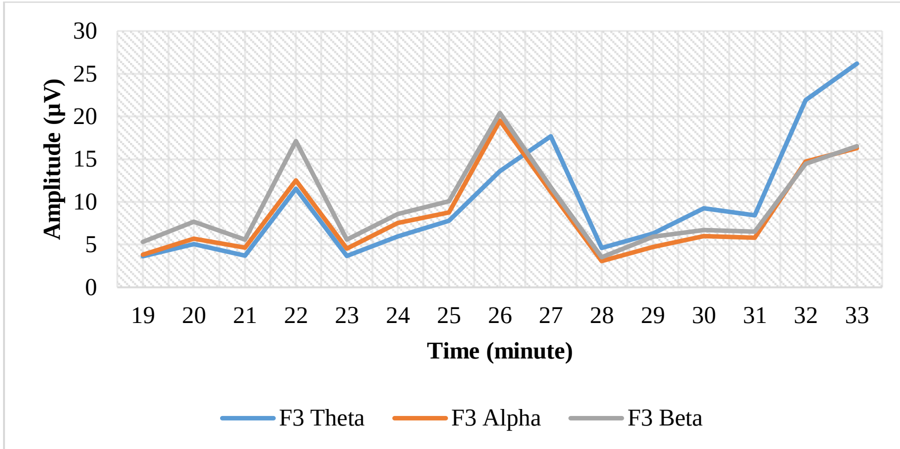


Figure 4.34 RMS Graphic on Respondent 3 at F3 by autodidact in the afternoon

Figure 4.35 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 26th minute, where the value of Beta, Theta, and Alpha was 11.2745, 6.2200, and 8.7506 µv at the 26th minute. Then, the amplitude of Theta (10.4236 µv) at the 27th minute increased and was always the greatest compare to amplitude of Alpha (6.7660 µv) and Beta (7.3857 µv).

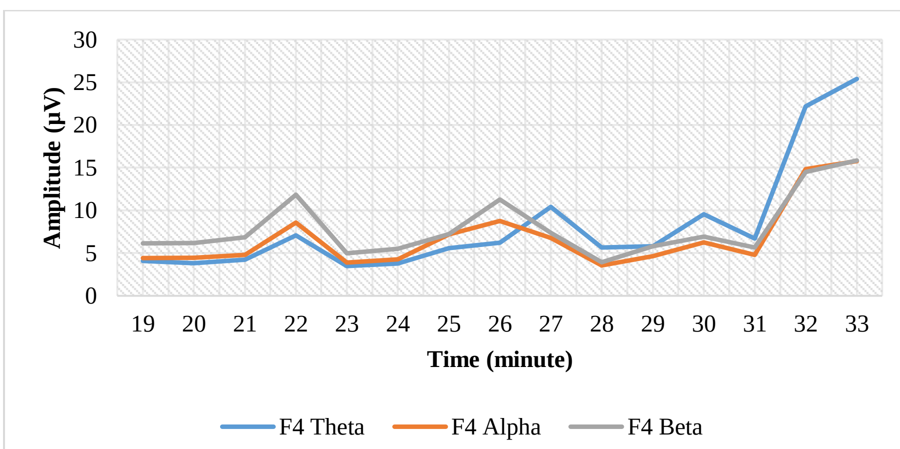


Figure 4.35 RMS Graphic on Respondent 3 at F4 by autodidact in the afternoon

Figure 4.36 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 26th minute, where the value of Beta, Theta, and Alpha was 10.2215, 6.3931, and 7.6586 µv at the 26th minute. Then, the amplitude of Theta (11.0999 µv) at the 27th minute increased and was always the greatest compare to amplitude of Alpha (6.8303 µv) and Beta (7.6883µv).

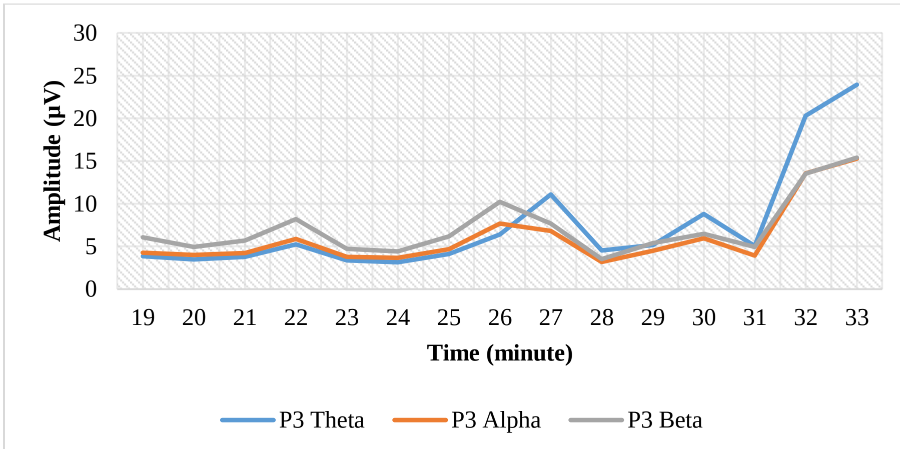


Figure 4.36 RMS Graphic on Respondent 3 at P3 by autodidact in the afternoon

Figure 4.37 shows the amplitude RMS graphic of third respondent's EEG final signal on autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 26th minute, where the value of Beta, Theta, and Alpha was 8.5976, 5.9093, and 7.0809 µv at the 26th minute. Then, the amplitude of Theta (12.6634 µv) at the 27th minute increased and was always the greatest compare to amplitude of Alpha (7.4625µv) and Beta (8.2407 µv).

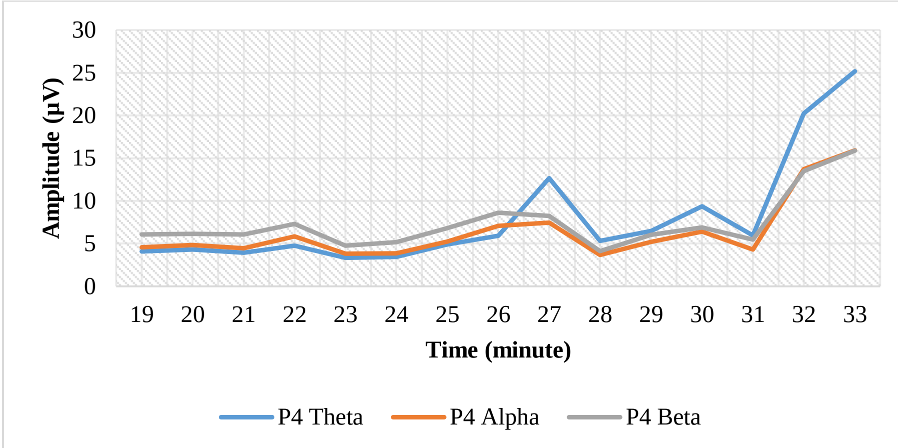


Figure 4.37 RMS Graphic on Respondent 3 at P4 by autodidact in the afternoon

Based on Figure 4.34 and Figure 4.35, the ability of respondent 3 to memorize and solve problems appeared until at the 26th minute. Then at the 27th minute, it decreased and respondent 3 felt sleepy. As well as shown on Figure 4.36 and Figure 4.37, the ability of respondent 3 to read and understand the lesson appeared until at the 26th minute. Then at the 27th minute, it decreased and respondent 3 felt sleepy. It indicated that respondent 3 had not focussed on Physics subject at the 27th minute during studying on autodidact in the afternoon.

d. Respondent 4

Figure 4.38 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 19th minute, where the value of Beta, Theta, and Alpha was 10.5801, 10.5690, and 7.4175 µv at the 19th minute. Then, the amplitude of Theta (19.2665 µv) at 20th minute increased and was the greatest compare to amplitude of Alpha (13.8420 µv) and Beta (17.7845 µv). At the 21st to 24th minute. The amplitude of Beta at the 21st to 24th minute increased again, yet decreased at the 25th minute. The amplitude of Theta (10.5793 µv) at the 25th minutes increased and was the greatest compare to amplitude of Alpha (6.3850 µv) and Beta (8.7903 µv).

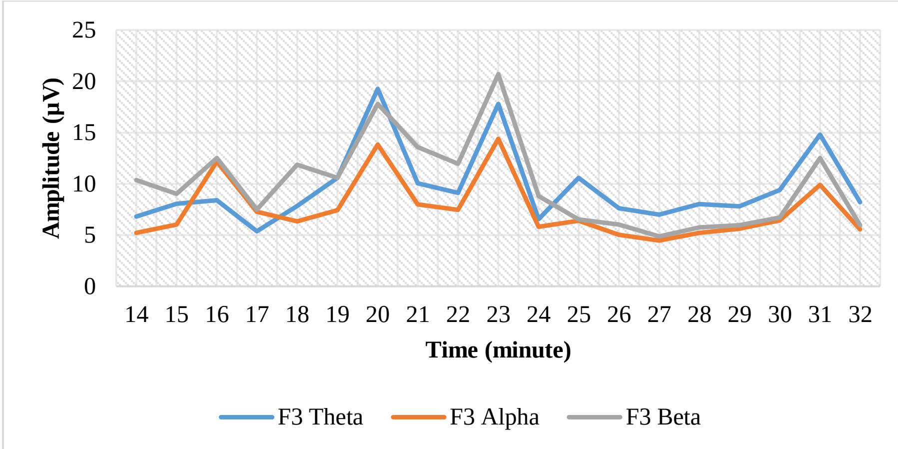


Figure 4.38 RMS Graphic on Respondent 4 at F3 by autodidact in the afternoon

Figure 4.39 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 24^{th} minute, where the value of Beta, Theta, and Alpha was 12.1313, 5.9231, and 6.6621 µv at the 24^{th} minute. Then, the amplitude of Theta (13.1314 µv) at the 25^{th} minute increased and was always the greatest compare to amplitude of Alpha (6.5406 µv) and Beta (6.9262 µv).

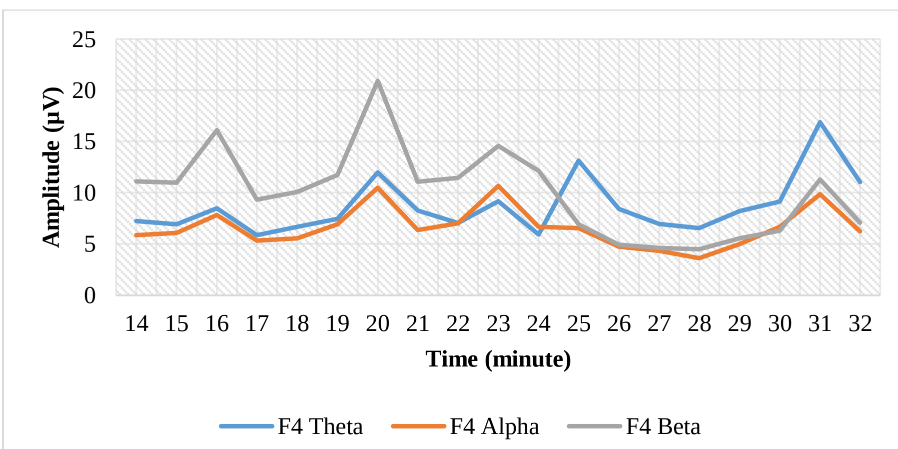


Figure 4.39 RMS Graphic on Respondent 4 at F4 by autodidact in the afternoon

Figure 4.40 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 24th minute, where the value of Beta, Theta, and Alpha was 10.9936, 6.1053, and 6.0158 µv at the 24th minute. Then, the amplitude of Theta (9.9660 µv) at the 25th minute increased and was always the greatest compare to amplitude of Alpha (4.8883 µv) and Beta (5.4153 µv).

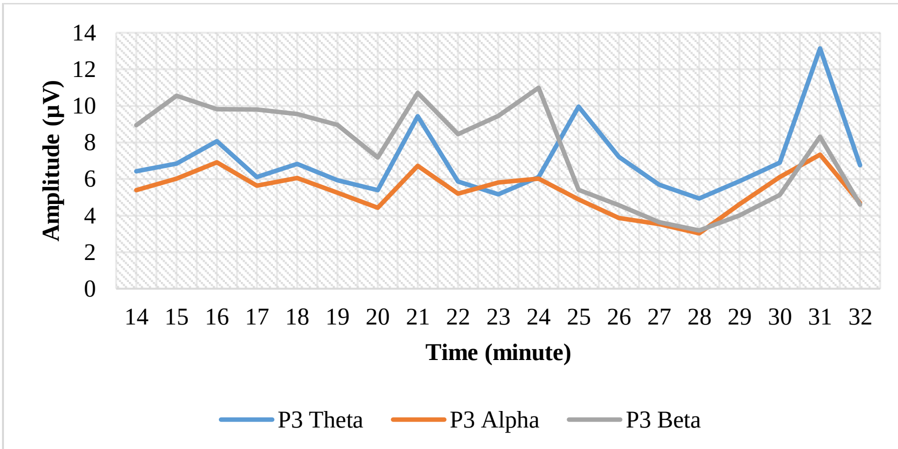


Figure 4.40 RMS Graphic on Respondent 4 at P3 by autodidact in the afternoon

Figure 4.41 shows the amplitude RMS graphic of fourth respondent's EEG final signal on autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was greater than Theta and Alpha until at the 24th minute, where the value of Beta, Theta, and Alpha was 12.1618, 6.6384, 7.1435 µv at the 24th minute. Then, the amplitude of Theta (11.6662 µv) at the 25th minute increased and was always the greatest compare to amplitude of Alpha (5.9402 µv) and Beta (6.4821 µv).

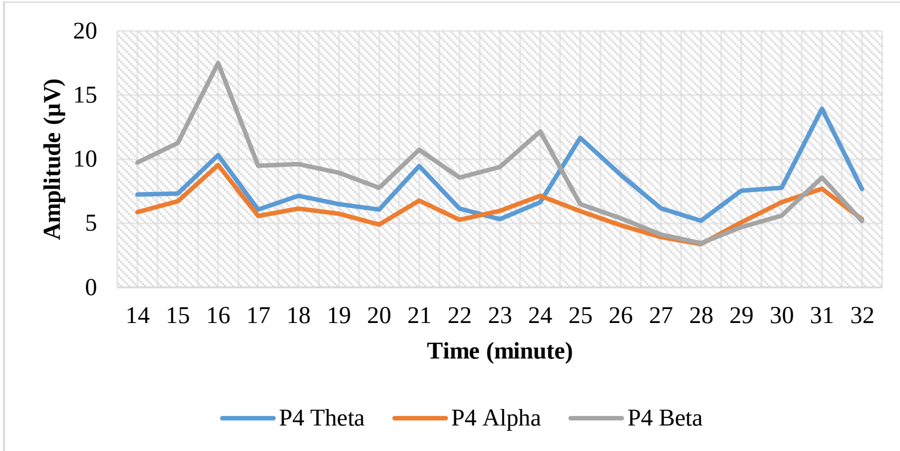


Figure 4.41 RMS Graphic on Respondent 4 at P4 by autodidact in the afternoon

Based on Figure 4.38 and Figure 4.39, the ability of respondent 4 to memorize and solve problems appeared until at the 24th minute. Then at the 25th minute, it decreased and respondent 4 felt sleepy. As well as shown on Figure 4.40 and Figure 4.41, the ability of respondent 4 to read and understand the lesson appeared until at the 24th minute. Then at the 25th minute, it decreased and respondent 4 felt sleepy. It indicated that respondent 4 had not focussed on Physics subject at the 25th minute during studying on autodidact in the afternoon.

4.2.2.3 Non-Autodidact in the Late Morning

a. Respondent 1

Figure 4.42 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the late morning at F3 channel. It shows that amplitude of Beta was always the greatest compare to Theta and Alpha until at the 81st minute, where the amplitude of Beta at the 80th minutes started to decrease. The value of Beta, Theta, and Alpha amplitude was 3.7257, 2.2428, and 1.9094 µv at the 81st minute. Then, the amplitude of Alpha and Theta fluctuated at 82nd minute. Amplitude alpha at the 82nd (3.3984 µv) was the greatest compare to amplitude of Theta (2.0918 µv) and Beta (3.3555 µv). Furthermore, the amplitude of Theta was the greatest at the 85th minute (5.7553 µv) and at the 88th minute (5.6805 µv) compare to amplitude of Alpha and Beta.

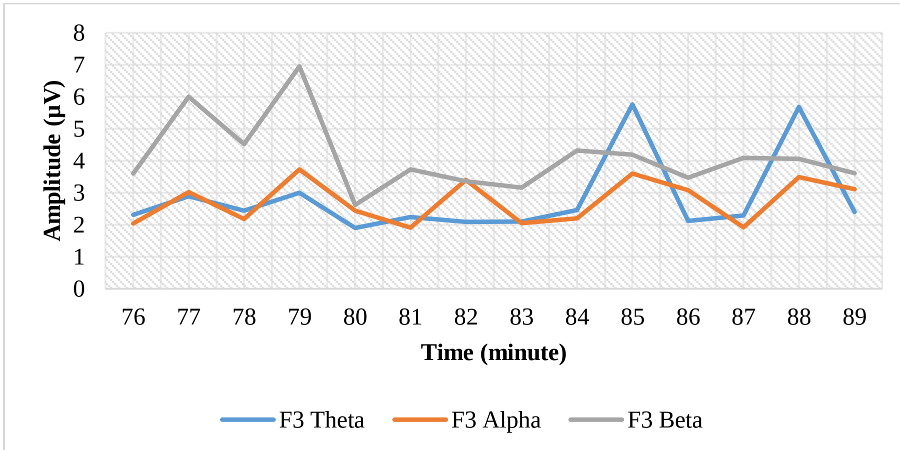


Figure 4.42 RMS Graphic on Respondent 1 at F3 by non-autodidact in the late morning

Figure 4.43 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the late morning at F4 channel. It shows that amplitude of Beta was always the greatest compare to Theta and Alpha until at the 79th minute, where the value of Beta, Theta, and Alpha amplitude was 4.3562, 2.5588, and 2.7716 µv at the 79th minute. Then, the amplitude of Alpha and Theta started fluctuating at the 80th minute. Amplitude alpha at the 80th minute (3.3984 µv), at the 82nd minute (3.6710 µv), and at the 86th minute (3.2769) was the greatest compare to amplitude of Theta and Beta. Furthermore, the amplitude of Theta was the greatest at the 85th minute (5.5458 µv) and at the 88th minute (5.4593 µv) compare to amplitude of Alpha and Beta.

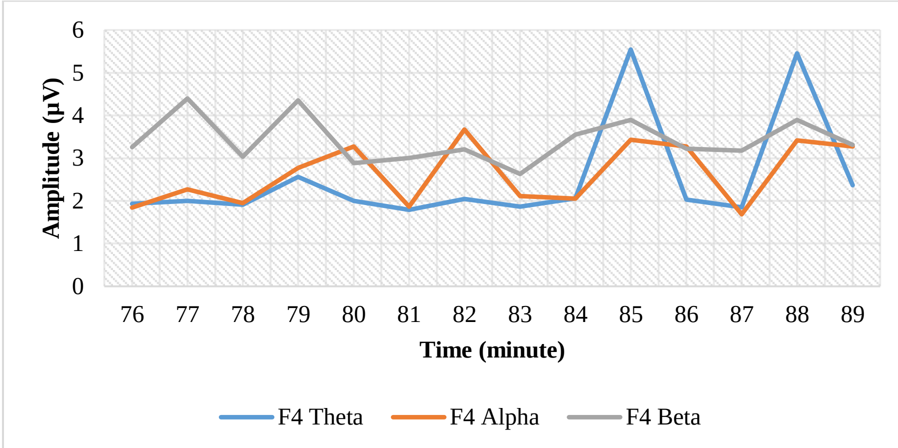


Figure 4.43 RMS Graphic on Respondent 1 at F4 by non-autodidact in the late morning

Figure 4.44 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the late morning at P3 channel. It shows that amplitude of Beta was always the greatest compare to Theta and Alpha until at the 79th minute, where the value of Beta, Theta, and Alpha amplitude was 4.7226, 2.1892, 3.5149 µv at the 79th minute. Then, the amplitude of Alpha and Theta started fluctuating at the 80th minute. Amplitude alpha at the 80th minute (3.5149 µv), at the 82nd minute (4.8199 µv), at the 86th minute (4.2909 µv), and at the 89th minute (4.4182 µv) was the greatest compare to amplitude of Theta and Beta. Furthermore, the amplitude of Theta was the greatest at the 85th minute (3.7587 µv) and at the 88th minute (3.7251µv) compare to amplitude of Alpha and Beta.

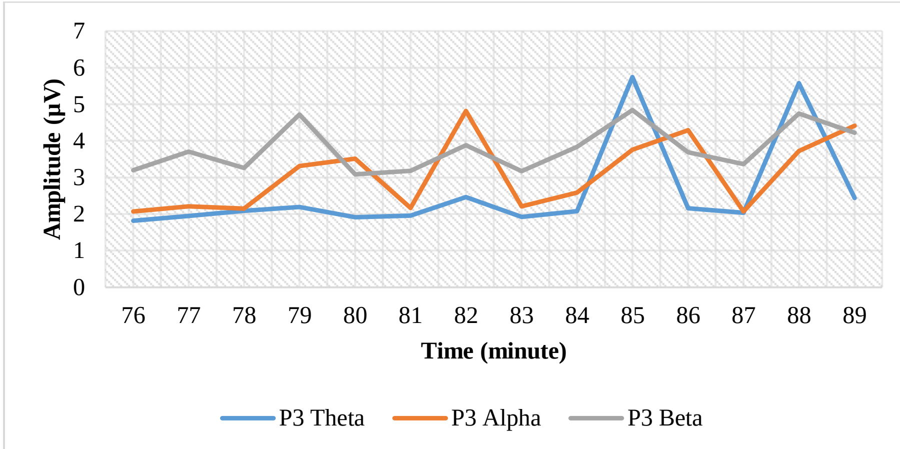


Figure 4.44 RMS Graphic on Respondent 1 at P3 by non-autodidact in the late morning

Figure 4.45 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the late morning at P4 channel. It shows that amplitude of Beta was always the greatest compare to Theta and Alpha until at the 79th minute, where the value of Beta, Theta, and Alpha amplitude was 3.9214, 1.9024, and 3.1048 µv at the 79th minute. Then, the amplitude of Alpha and Theta started fluctuating at the 80th minute. Amplitude alpha at the 80th minute (3.1048 µv), at the 82nd minute (4.2237 µv), at the 86th minute (3.8063 µv), and at the 89th minute (3.8456 µv) was the greatest compare to amplitude of Theta and Beta. Furthermore, the amplitude of Theta was the greatest at the 85th minute (5.6060 µv) and at the 88th minute (3.4638 µv) compare to amplitude of Alpha and Beta.

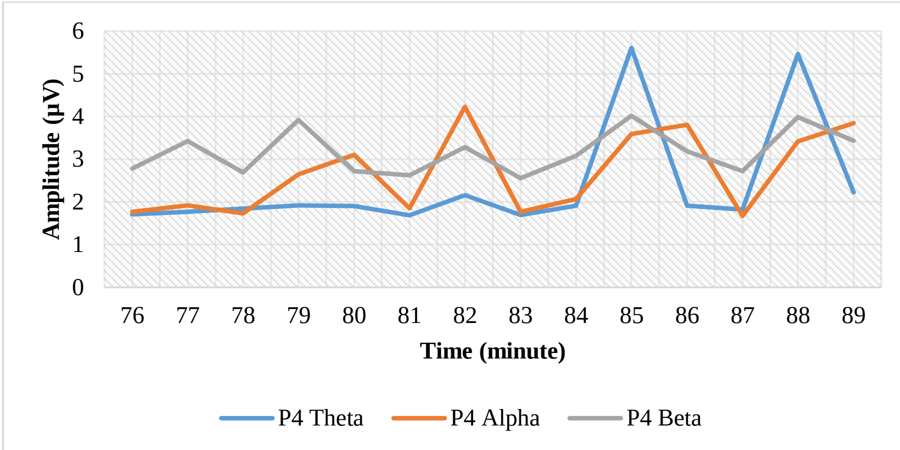


Figure 4.45 RMS Graphic on Respondent 1 at P4 by non-autodidact in the late morning

Based on Figure 4.42 and Figure 4.43, the ability of respondent 1 to memorize and solve problems appeared until at the 81st minute. Then at the 82nd minute, it decreased and respondent 1 had no concentration then felt sleepy at the 85th minute. As well as shown on Figure 4.44 and Figure 4.45, the ability of respondent 1 to read and understand the lesson appeared until at the 79th minute. Then at the 80th minute, it decreased and respondent 1 had no concentration then felt sleepy. It indicated that respondent 1 had not focussed on Physics subject at the 82nd minute during studying on non-autodidact in the late morning.

b. Respondent 2

Figure 4.46 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the late morning at F3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 56th minute, where the value of Beta, Theta, and Alpha amplitude was 3.2371, 1.6989, and 1.8696 µv at the 56th minute. Then, the amplitude of Alpha and Theta started fluctuating at the 57th minute, while the amplitude of Beta was the lowest. Amplitude of Theta at the 57th minute (6.8598 µv) started increasing and was the greatest compare to amplitude of Alpha (4.1762 µv) and Beta (3.7114 µv).

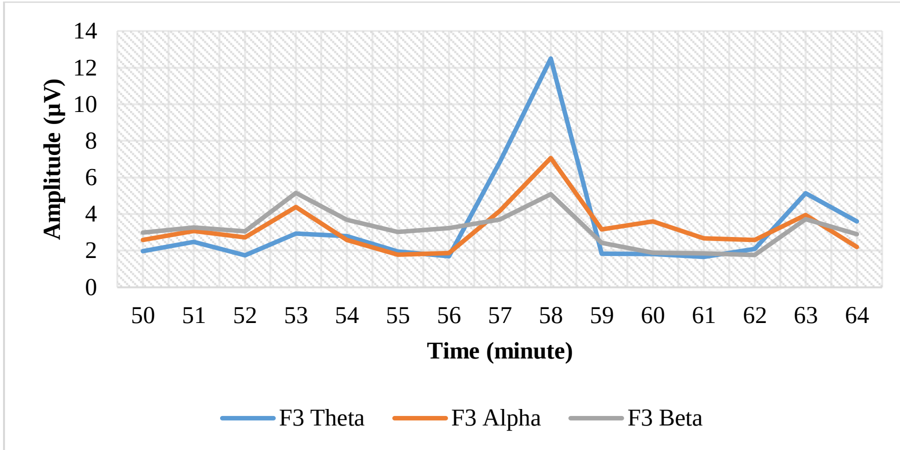


Figure 4.46 RMS Graphic on Respondent 2 at F3 by non-autodidact in the late morning

Figure 4.47 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the late morning at F4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 56th minute, where the value of Beta, Theta, and Alpha amplitude was 2.4175, 2.1551, and 1.6760 µv at the 56th minute. Then, the amplitude of Alpha and Theta started fluctuating at the 57th minute, while the amplitude of Beta was the lowest. Amplitude of Theta at the 57th minute (7.6446 µv) started increasing and was the greatest compare to amplitude of Alpha (4.6061 µv) and Beta (5.2286 µv).

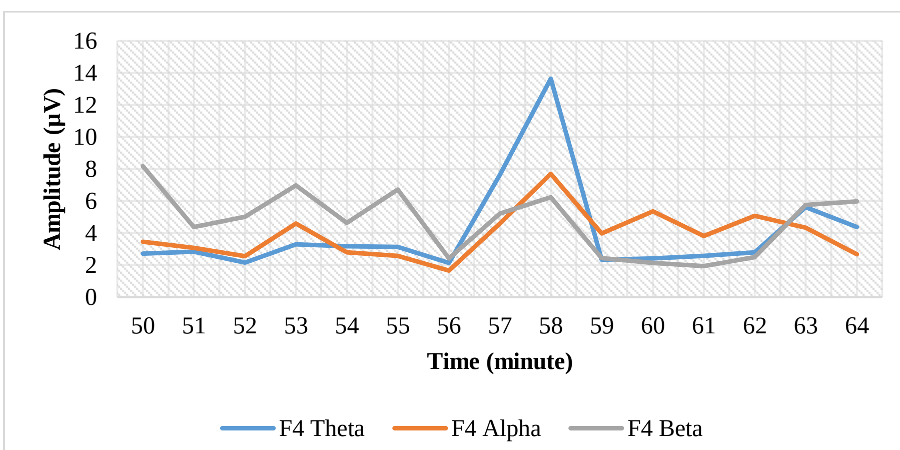


Figure 4.47 RMS Graphic on Respondent 2 at F4 by non-autodidact in the late morning

Figure 4.48 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the late morning at P3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 56th minute, where the value of Beta, Theta, and Alpha amplitude was 3.3089, 2.3668, and 1.8540 µv at the 56th minute. Then, the amplitude of Alpha and Theta started fluctuating at the 57th minute, while the amplitude of Beta was the lowest. Amplitude of Theta at the 57th minute (6.9842 µv) started increasing and was the greatest compare to amplitude of Alpha (4.1828 µv) and Beta (4.3239 µv).

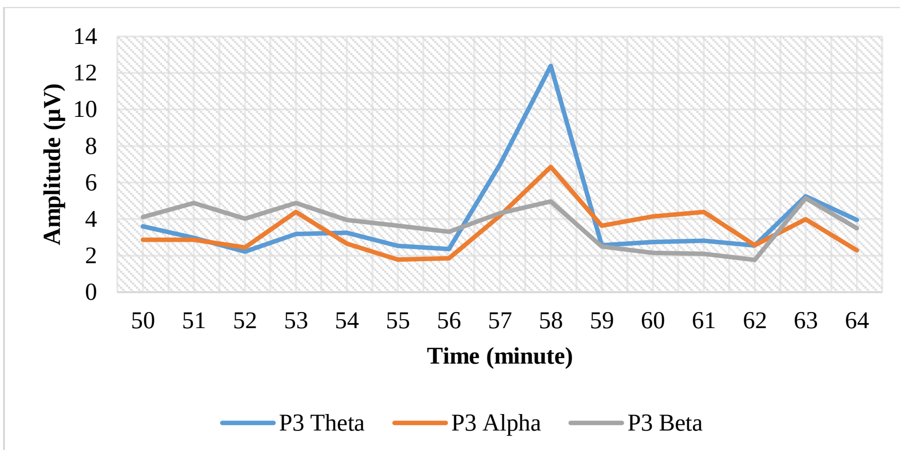


Figure 4.48 RMS Graphic on Respondent 2 at P3 by non-autodidact in the late morning

Figure 4.49 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the late morning at P4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 56th minute, where the value of Beta, Theta, and Alpha amplitude was 2.4997, 1.5873, and 1.6375 µv at the 56th minute. Then, the amplitude of Alpha and Theta started fluctuating at 57th minute, while the amplitude of Beta was the lowest. Amplitude of Theta at the 57th minute (7.0204 µv) started increasing and was the greatest compare to amplitude of Alpha (4.1804 µv) and Beta (3.5246 µv).

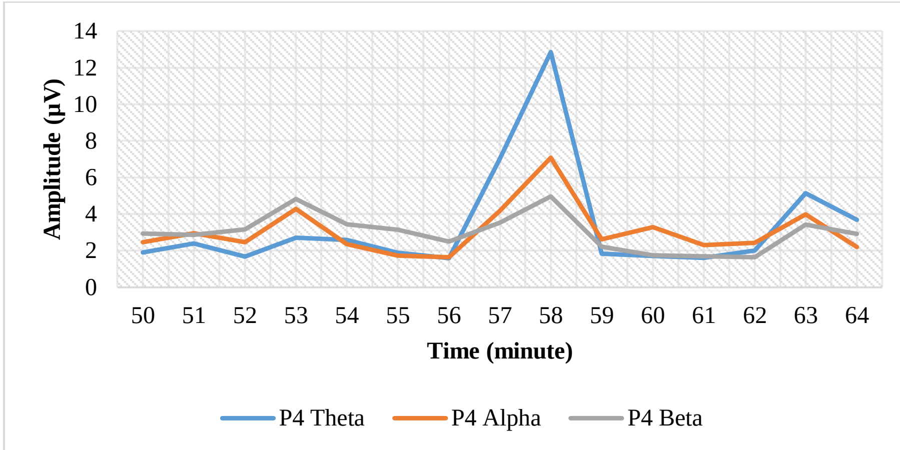


Figure 4.49 RMS Graphic on Respondent 2 at P4 by non-autodidact in the late morning

Based on Figure 4.46 and Figure 4.47, the ability of respondent 2 to memorize and solve problems appeared until at the 56th minute. Then at the 57th minute, it decreased and respondent 2 had no concentration and felt sleepy. As well as shown on Figure 4.48 and Figure 4.49, the ability of respondent 2 to read and understand the lesson appeared until at the 56th minute. Then at the 57th minute, it decreased and respondent 2 had no concentration and felt sleepy. It indicated that respondent 2 had not focussed on Physics subject at the 57th minute during studying on non-autodidact in the late morning.

c. Respondent 3

Figure 4.50 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the late morning at F3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 65th minute, where the value of Beta, Theta, and Alpha amplitude was 5.8887, 3.5721, and 3.2775 µv at the 65th minute. Then, the amplitude of Alpha and Theta started fluctuating at the 66th minute, while the amplitude of Beta was the lowest. Amplitude of Alpha at the 66th minute (4.5921 µv) started increasing and was the greatest compare to amplitude of Theta (3.1837 µv) and Beta (3.0305 µv).

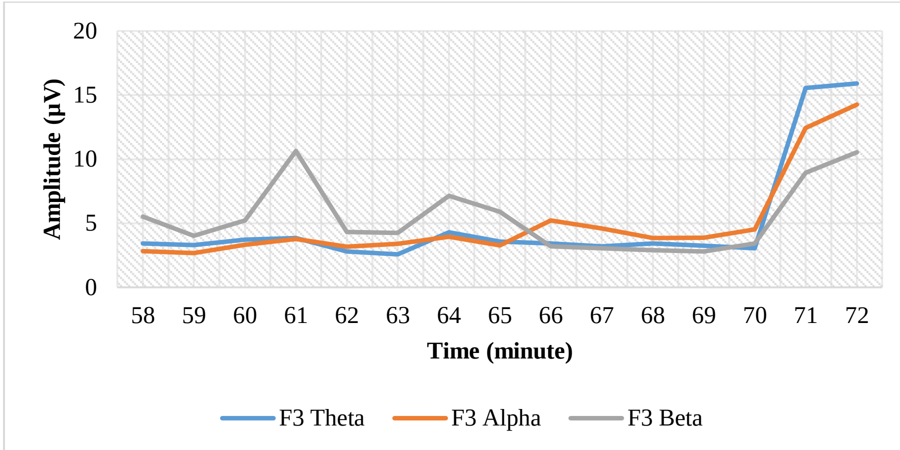


Figure 4.50 RMS Graphic on Respondent 3 at F3 by non-autodidact in the late morning

Figure 4.51 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the late morning at F4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 65^{th} minute, where the value of Beta, Theta, and Alpha amplitude was 4.4997, 2.5615, and 3.1929 µv at the 65^{th} minute. Then, the amplitude of Alpha and Theta started fluctuating at the 66^{th} minute, while the amplitude of Beta was the lowest. Amplitude of Alpha at 66^{th} minute (3.7154 µv) started increasing and was the greatest compare to amplitude of Theta (2.5905 µv) and Beta (3.3933 µv).

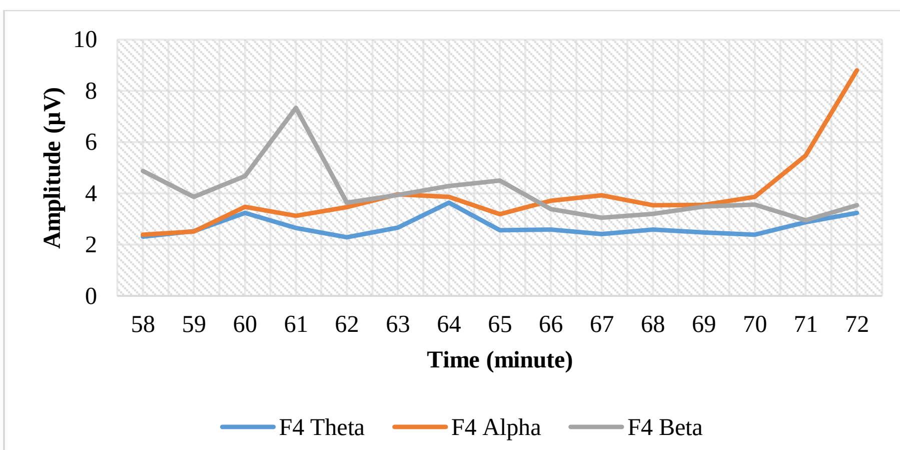


Figure 4.51 RMS Graphic on Respondent 3 at F4 by non-autodidact in the late morning

Figure 4.52 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the late morning at P3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 61st minute, where the value of Beta, Theta, and Alpha amplitude was 3.9008, 1.8860, and 2.8914 µv at the 61st minute. Then, the amplitude of Alpha and Beta started fluctuating at the 62nd minute. Alpha was the greatest among others at the 62nd to 64th, 66th, 70th, and 72nd minute. Meanwhile, Beta was the greatest among others at the 65th, 67th to 69th, and 71st minute.

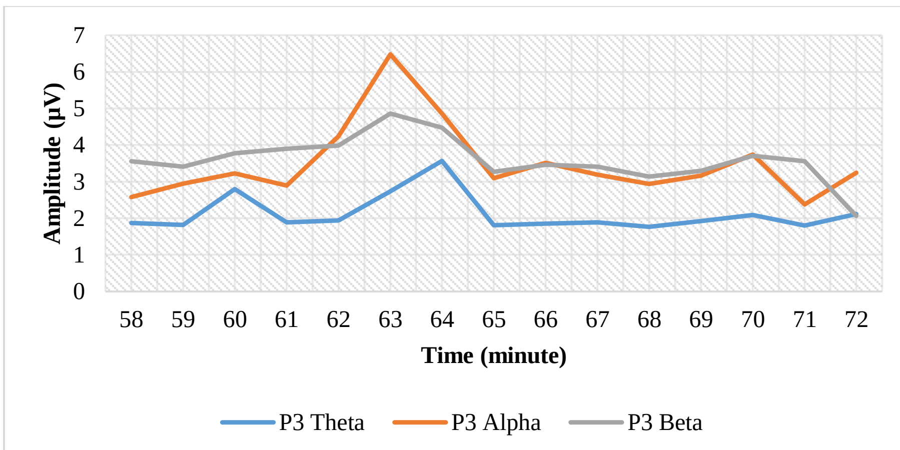


Figure 4.52 RMS Graphic on Respondent 3 at P3 by non-autodidact in the late morning

Figure 4.53 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the late morning at P4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 59th minute, where the value of Beta, Theta, and Alpha amplitude was 3.3634, 1.7405, and 3.2064 µv at the 59th minute. Then, the amplitude of Alpha and Beta started fluctuating at the 60th minute while the amplitude of Alpha was predominant higher than the amplitude of Beta.

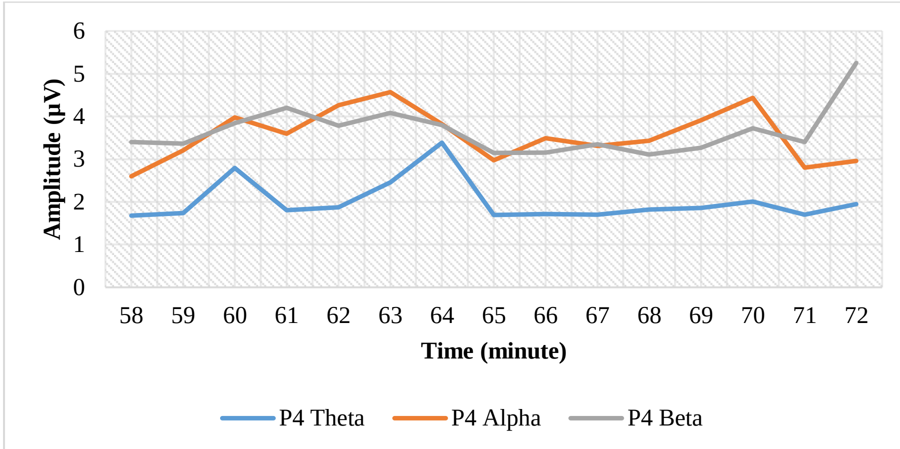


Figure 4.53 RMS Graphic on Respondent 3 at P4 by non-autodidact in the late morning

Based on Figure 4.50 and Figure 4.51, the ability of respondent 3 to memorize and solve problems appeared until at the 65th minute. Then at the 66th minute, it decreased and respondent 3 had no concentration. As well as shown on Figure 4.52 and Figure 4.53, the ability of respondent 3 to read and understand the lesson appeared until at the 61st minute. Then at the 62nd minute, it decreased and respondent 3 had no concentration. It indicated that respondent 3 had not focussed on Physics subject at the 66th minute during studying on non-autodidact in the late morning.

d. Respondent 4

Figure 4.54 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the late morning at F3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 56th minute, where the value of Beta, Theta, and Alpha amplitude was 5.0257, 4.4861, and 4.2268 µv at the 56th minute. Then, the amplitude of Theta and Alpha increased at the 57th minute where Theta and Alpha was predominant higher than Beta after the 57th minute. The value of Theta, Alpha, and Beta amplitude at the 57th minute was 5.5577, 5.0168, and 5.4678 µv.

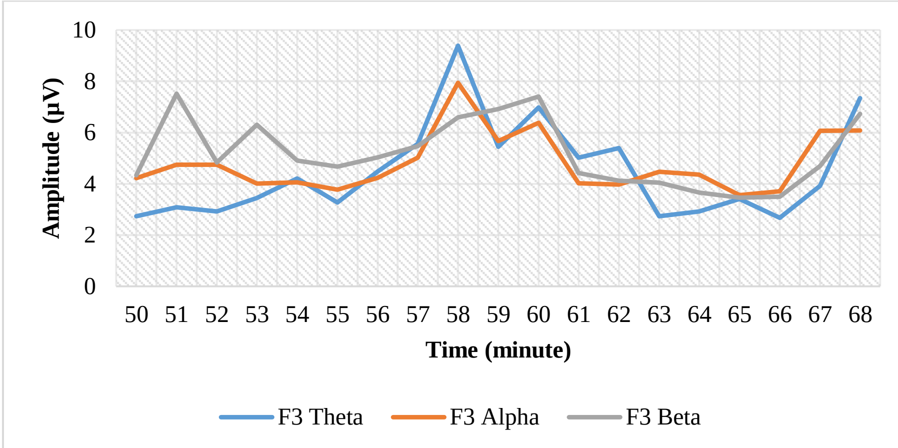


Figure 4.54 RMS Graphic on Respondent 4 at F3 by non-autodidact in the late morning

Figure 4.55 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the late morning at F4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 57th minute, where the value of Beta, Theta, and Alpha amplitude was 6.3680, 5.1899, and 4.7779 µv at the 57th minute. Then, the amplitude of Theta and Alpha increased at the 58th minute where Theta and Alpha was predominant higher than Beta after the 62nd minute. The value of Theta, Alpha, and Beta amplitude at the 58th minute was 8.9971, 7.3735, and 6.2915 µv.

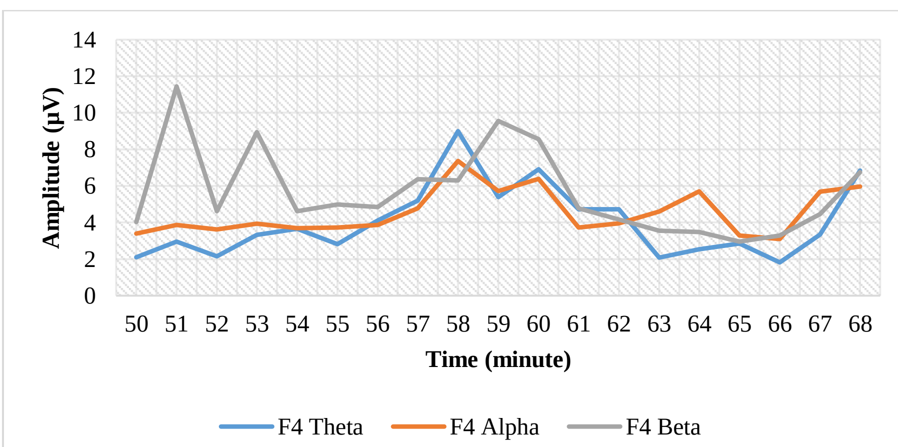


Figure 4.55 RMS Graphic on Respondent 4 at F4 by non-autodidact in the late morning

Figure 4.56 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the late morning at P3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 57th minute, where the value of Beta, Theta, and Alpha amplitude was 5.4876, 5.3140, 4.8419 µv at the 57th minute. Then, the amplitude of Theta and Alpha increased at the 58th minute where Theta and Alpha was predominant higher than Beta after the 61st minute. The value of Theta, Alpha, and Beta amplitude at the 58th minute was 9.3799, 7.4611, and 6.6303 µv.

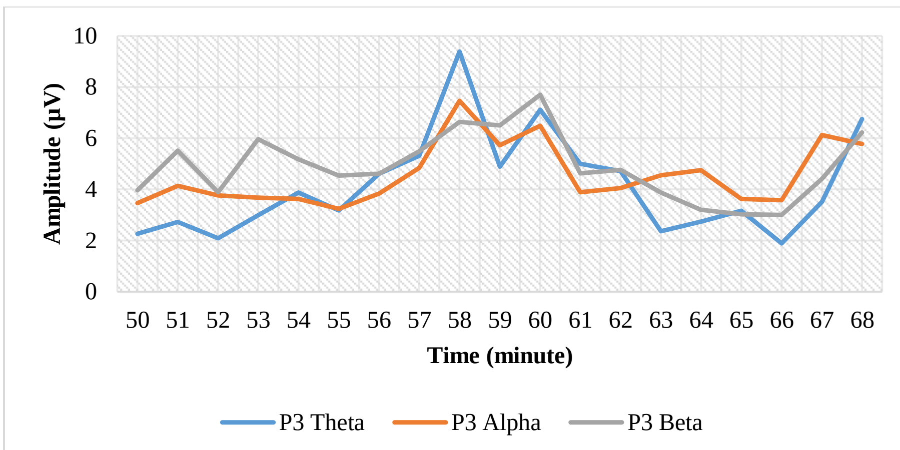


Figure 4.56 RMS Graphic on Respondent 4 at P3 by non-autodidact in the late morning

Figure 4.57 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the late morning at P4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 57th minute, where the value of Beta, Theta, and Alpha amplitude was 5.0671, 4.8549, and 4.8678 µv at the 57th minute. Then, the amplitude of Theta and Alpha increased at the 58th minute where Theta and Alpha was predominant higher than Beta after the 61st minute. The value of Theta, Alpha, and Beta amplitude at the 58th minute was 8.6575, 7.4332, and 6.4409 µv.

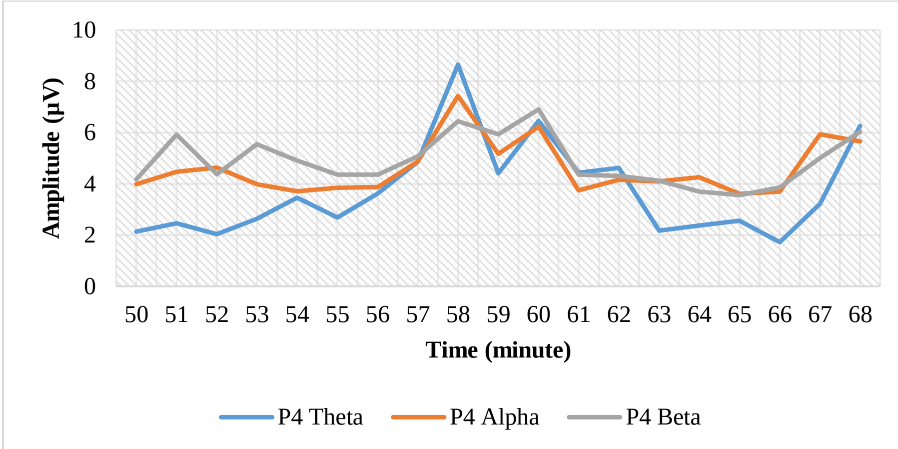


Figure 4.57 RMS Graphic on Respondent 4 at P4 by non-autodidact in the late morning

Based on Figure 4.54 and Figure 4.55, the ability of respondent 4 to memorize and solve problems appeared until at the 56th minute. Then at the 57th minute, it decreased and respondent 4 felt sleepy and had no concentration. As well as shown on Figure 4.56 and Figure 4.57, the ability of respondent 4 to read and understand the lesson appeared until at the 57th minute. Then at the 58th minute, it decreased and respondent 4 felt sleepy and had no concentration. It indicated that respondent 4 had not focussed on Physics subject at the 57th minute during studying on non-autodidact in the late morning.

4.2.2.4 Non-Autodidact in the Afternoon

a. Respondent 1

Figure 4.58 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 19th minute, where the value of Beta, Theta, and Alpha amplitude was 3.2666, 2.3876, and 2.0760 µv at the 19th minute. Then, the amplitude of Theta and Alpha increased at the 20th minute whereas the amplitude of Beta was the lowest among others. The value of

Theta, Alpha, and Beta amplitude at the 20th minute was 3.5549, 2.5376, and 3.2191 µv.

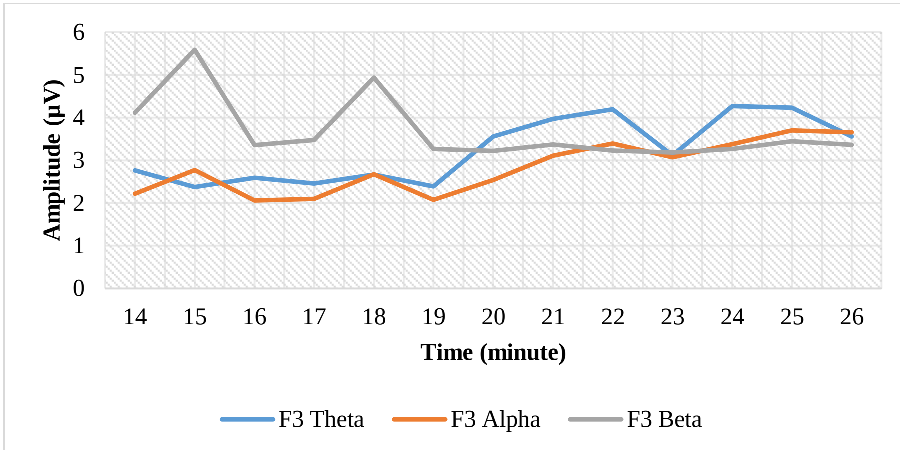


Figure 4.58 RMS Graphic on Respondent 1 at F3 by non-autodidact in the afternoon

Figure 4.59 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 20th minute, where the value of Beta, Theta, and Alpha amplitude was 2.9661, 2.7277, and 2.3760 µv at the 20th minute. Then, the amplitude of Theta and Alpha increased at the 21st minute whereas the amplitude of Beta was the lowest among others. The value of Theta, Alpha, and Beta amplitude at the 21st minute was 3.5784, 3.1291, and 3.2746 µv.

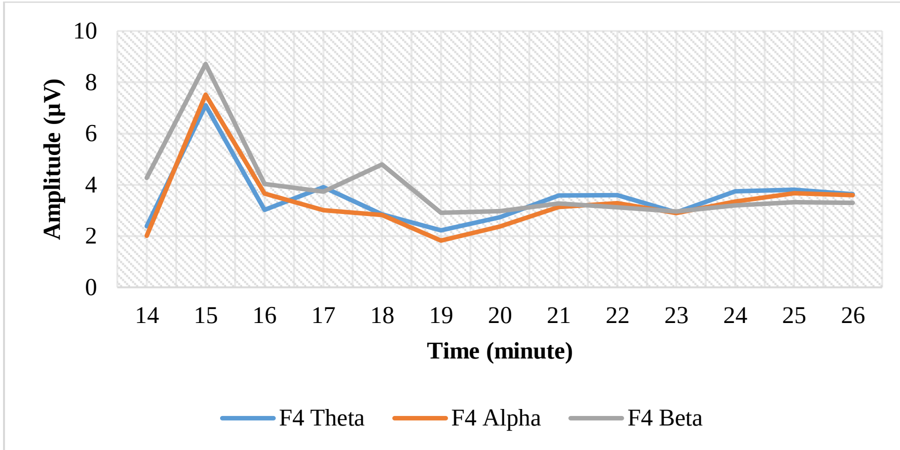


Figure 4.59 RMS Graphic on Respondent 1 at F4 by non-autodidact in the afternoon

Figure 4.60 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 19th minute, where the value of Beta, Theta, and Alpha amplitude was 3.0003, 2.2568, and 2.0444 µv at the 19th minute. Then, the amplitude of Theta increased at the 20th minute whereas the amplitude of Beta was the lowest among others. The value of Theta, Alpha, and Beta amplitude at the 20th minute was 2.9737, 2.3341, and 2.8317 µv.

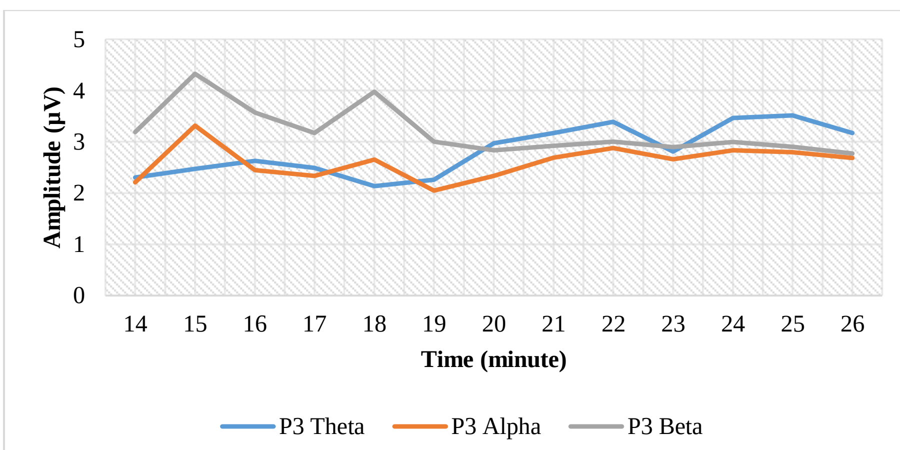


Figure 4.60 RMS Graphic on Respondent 1 at P3 by non-autodidact in the afternoon

Figure 4.61 shows the amplitude RMS graphic of first respondent's EEG final signal on non-autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 19th minute, where the value of Beta, Theta, and Alpha amplitude was 2.7090, 2.4481, and 2.0273 µv at the 19th minute. Then, the amplitude of Theta increased at 20th minute whereas the amplitude of Beta was the lowest among others. The value of Theta, Alpha, and Beta amplitude at the 20th minute was 3.0546, 2.1565, and 2.5312 µv.

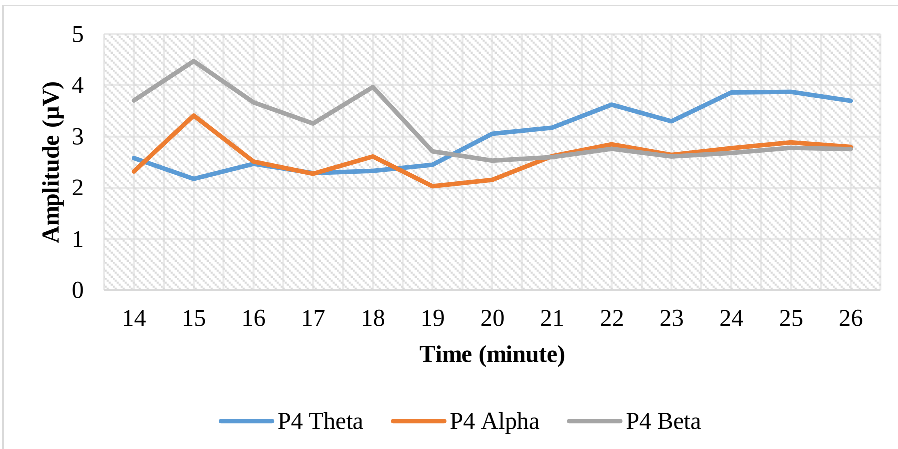


Figure 4.61 RMS Graphic on Respondent 1 at P4 by non-autodidact in the afternoon

Based on Figure 4.58 and Figure 4.59, the ability of respondent 1 to memorize and solve problems appeared until at the 20th minute. Then at the 21st minute, it decreased and respondent 1 felt sleepy and had no concentration. As well as shown on Figure 4.60 and Figure 4.61, the ability of respondent 1 to read and understand the lesson appeared until at the 19th minute. Then at the 20th minute, it decreased and respondent 1 felt sleepy. It indicated that respondent 1 had not focussed on Physics subject at the 21st minute during studying on non-autodidact in the afternoon.

b. Respondent 2

Figure 4.62 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 38th minute, where the value of Beta, Theta, and Alpha amplitude was 5.4506, 2.4180, 3.7837 µv at the 8th minute. Then, the amplitude of Theta increased at the 39th minute whereas the amplitude of Beta was the lowest among others. The value of Theta, Alpha, and Beta amplitude at the 39th minute was 5.0342, 4.1434, and 4.1370 µv.

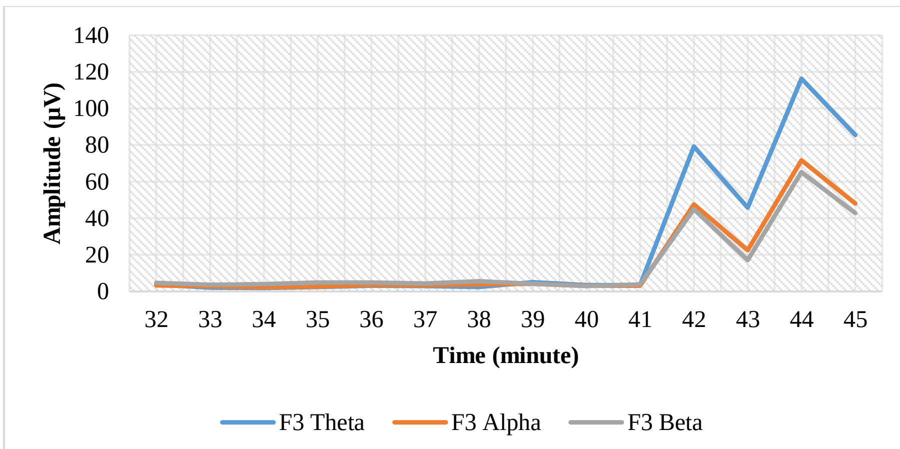


Figure 4.62 RMS Graphic on Respondent 2 at F3 by non-autodidact in the afternoon

Figure 4.63 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 35th minute, where the value of Beta, Theta, and Alpha amplitude was 3.4522, 2.7869, and 3.2441 µv at the 35th minute. Then, the amplitude of Alpha at the 36th minute (3.8988 µv) continued increasing and the highest among Theta (2.6614 µv) and Beta (3.6941 µv). Furthermore, it followed with the increasing of Theta amplitude at the 42nd minute (15.9908 µv) which was the greatest among Alpha (11.1126 µv) and Beta (9.5930 µv).

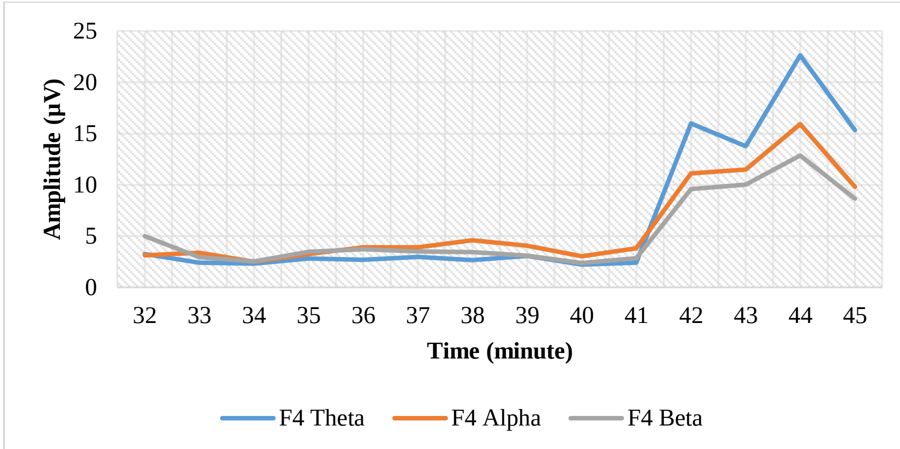


Figure 4.63 RMS Graphic on Respondent 2 at F4 by non-autodidact in the afternoon

Figure 4.64 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 32nd minute, where the value of Beta, Theta, and Alpha amplitude was 3.6124, 2.6404, and 3.2586 µv at the 32nd minute. Then, the amplitude of Alpha at the 33rd minute (4.1830 µv) continued increasing and the highest among Theta (2.3850 µv) and Beta (2.9895 µv). Furthermore, it followed with the increasing of Theta amplitude at the 42nd minute (15.4954 µv) which was the greatest among Alpha (10.9037 µv) and Beta (9.6135 µv).

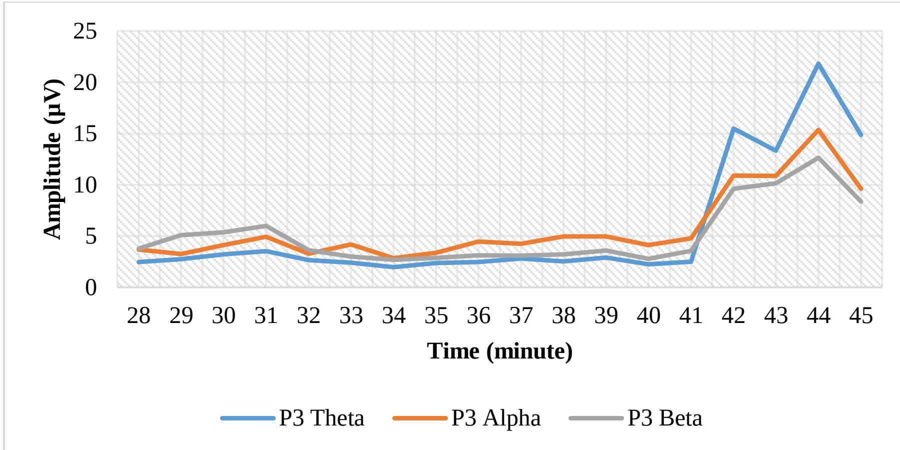


Figure 4.64 RMS Graphic on Respondent 2 at P3 by non-autodidact in the afternoon

Figure 4.67 shows the amplitude RMS graphic of second respondent's EEG final signal on non-autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 32nd minute, where the value of Beta, Theta, and Alpha amplitude was 3.4079, 2.2729, and 2.5711 µv at the 32nd minute. Then, the amplitude of Alpha at the 33rd minute (3.0892 µv) continued increasing and the highest among Theta (1.8611 µv) and Beta (2.5775 µv). Furthermore, it followed with the increasing of Theta amplitude at the 42nd minute (14.6079 µv) which was the greatest among Alpha (9.9631 µv) and Beta (8.7888 µv).

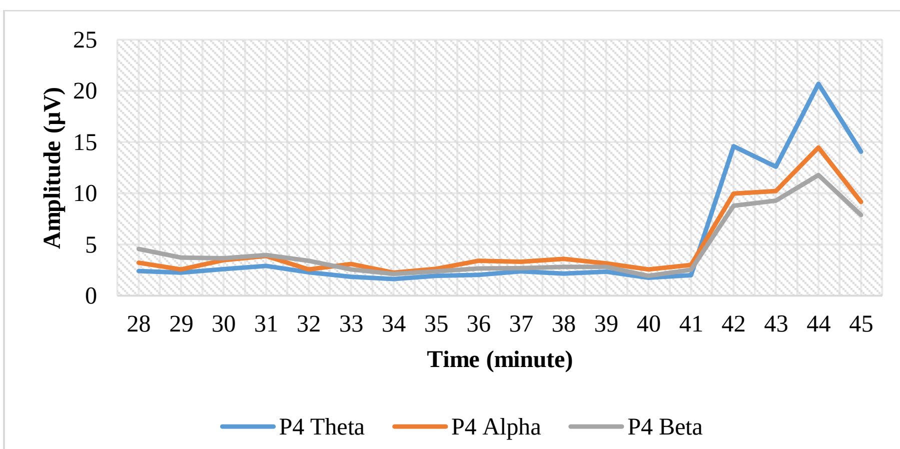


Figure 4.65 RMS Graphic on Respondent 2 at P4 by non-autodidact in the afternoon

Based on Figure 4.62 and Figure 4.63, the ability of respondent 2 to memorize and solve problems appeared until at the 38th minute. Then at the 39th minute, it decreased and respondent 2 had no concentration and felt sleepy. As well as shown on Figure 4.64 and Figure 4.65, the ability of respondent 2 to read and understand the lesson appeared until at the 32nd minute. Then at the 33rd minute, it decreased and respondent 2 had no concentration and felt sleepy. It indicated that respondent 2 had not focussed on Physics subject at the 39th minute during studying on non-autodidact in the afternoon.

c. Respondent 3

Figure 4.66 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 30th minute, where the value of Beta, Theta, and Alpha amplitude was 3.1792, 2.7329, and 2.9505 µv at the 30th minute. Then, the amplitude of Theta increased at 31st minute where Theta was predominant the highest among others after the 31st minute. The value of Theta, Alpha, and Beta amplitude at the 31st minute was 5.7512, 2.9260, and 2.9382 µv.

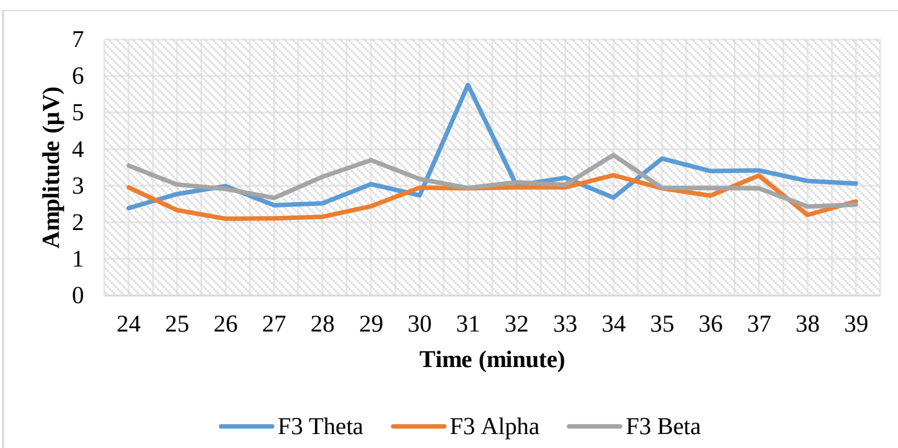


Figure 4.66 RMS Graphic on Respondent 3 at F3 by non-autodidact in the afternoon

Figure 4.67 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 29th minute, where the value of Beta, Theta, and Alpha amplitude was 2.9276, 2.4683, and 2.3273 µv at the 29th minute. Then, the amplitude of Theta and Alpha increased at 30th minute where Theta was predominant higher after the 30th minute. The value of Theta, Alpha, and Beta amplitude at the 30th minute was 4.9681, 2.9081, and 3.1079 µv.

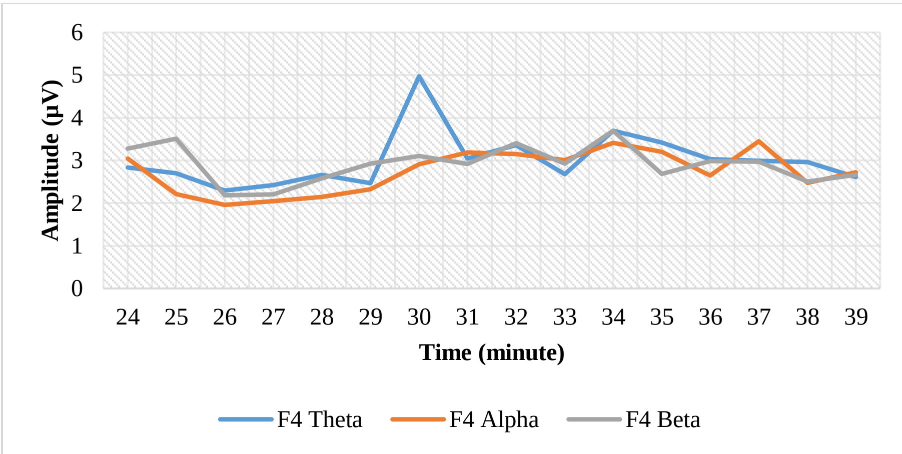


Figure 4.67 RMS Graphic on Respondent 3 at F4 by non-autodidact in the afternoon

Figure 4.68 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 29th minute, where the value of Beta, Theta, and Alpha amplitude was 2.5072, 1.6492, and 2.4071 µv at the 29th minute. Then, the amplitude of Theta and Alpha increased at 30th minute where Alpha was predominant higher after the 30th minute. The value of Theta, Alpha, and Beta amplitude at the 30th minute was 4.5232, 3.0707, and 2.9177 µv.

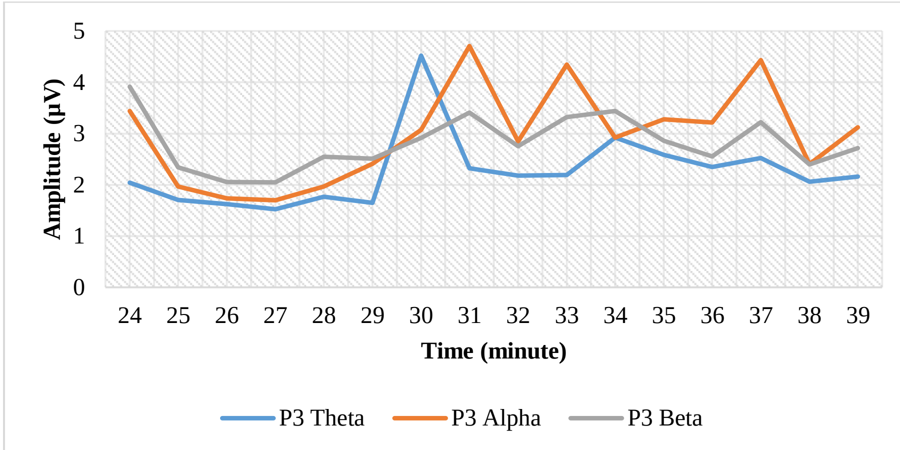


Figure 4.68 RMS Graphic on Respondent 3 at P3 by non-autodidact in the afternoon

Figure 4.69 shows the amplitude RMS graphic of third respondent's EEG final signal on non-autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 29th minute, where the value of Beta, Theta, and Alpha amplitude was 2.5929, 1.7397, and 2.4292 µv at the 29th minute. Then, the amplitude of Theta and Alpha increased at 30th minute where Alpha was predominant higher after the 30th minute. The value of Theta, Alpha, and Beta amplitude at the 30th minute was 4.2243, 2.9057, and 2.9428 µv.

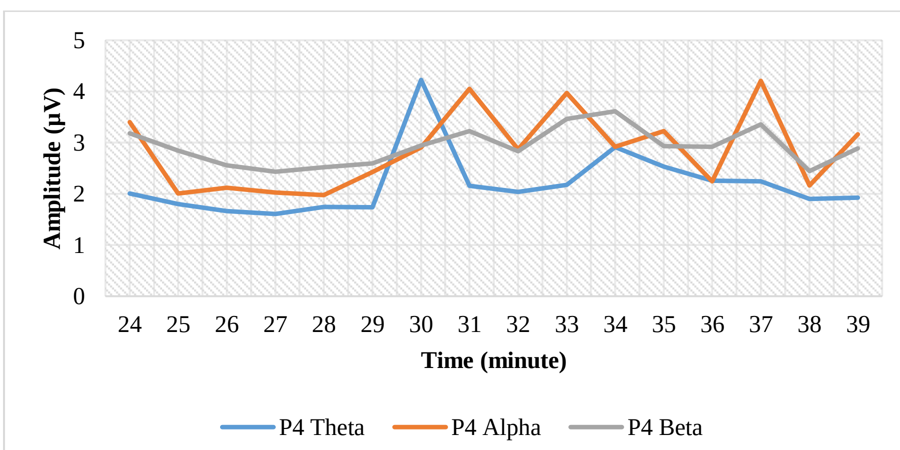


Figure 4.69 RMS Graphic on Respondent 3 at P4 by non-autodidact in the afternoon

Based on Figure 4.66 and Figure 4.67, the ability of respondent 3 to memorize and solve problems appeared until at the 30th minute. Then at the 31st minute, it decreased and respondent 3 felt sleepy. As well as shown on Figure 4.68 and Figure 4.69, the ability of respondent 3 to read and understand the lesson appeared until at the 29th minute. Then at the 30th minute, it decreased and respondent 3 had no concentration and felt sleepy. It indicated that respondent 3 had not focussed on Physics subject at the 31st minute during studying on non-autodidact in the afternoon.

d. Respondent 4

Figure 4.70 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the afternoon at F3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 21st minute, where the value of Beta, Theta, and Alpha amplitude was 6.2334, 4.1770, 5.6795 µv at the 21st minute. Then, the amplitude of Theta and Alpha increased at the 22nd minute where Alpha was predominant higher after the 22nd minute. The value of Theta, Alpha, and Beta amplitude at the 22nd minute was 3.8766, 3.6335, and 3.6802 µv.

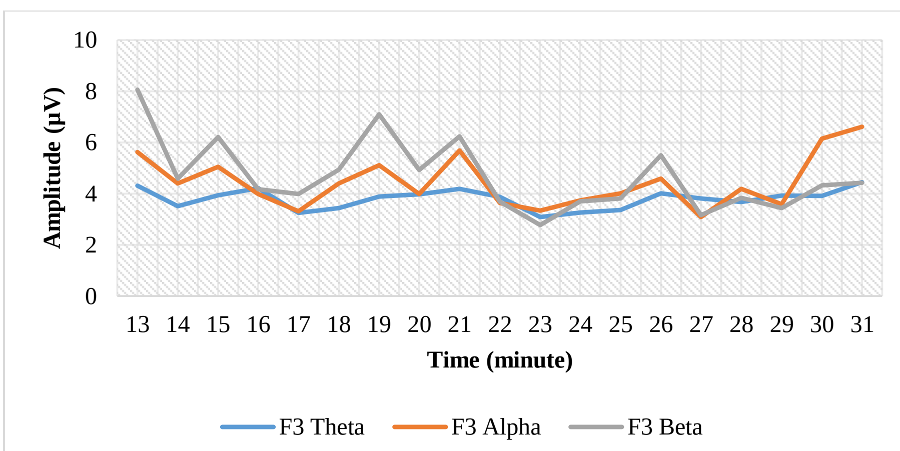


Figure 4.70 RMS Graphic on Respondent 4 at F3 by non-autodidact in the afternoon

Figure 4.71 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the afternoon at F4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 21st minute, where the value of Beta, Theta, and Alpha amplitude was 5.0142, 4.8391, and 5.2399 µv at the 21st minute. Then, the amplitude of Theta and Alpha increased at the 22nd minute where Theta was predominant higher after the 22nd minute. The value of Theta, Alpha, and Beta amplitude at the 22nd minute was 23.3584, 15.1817, and 16.4712 µv.

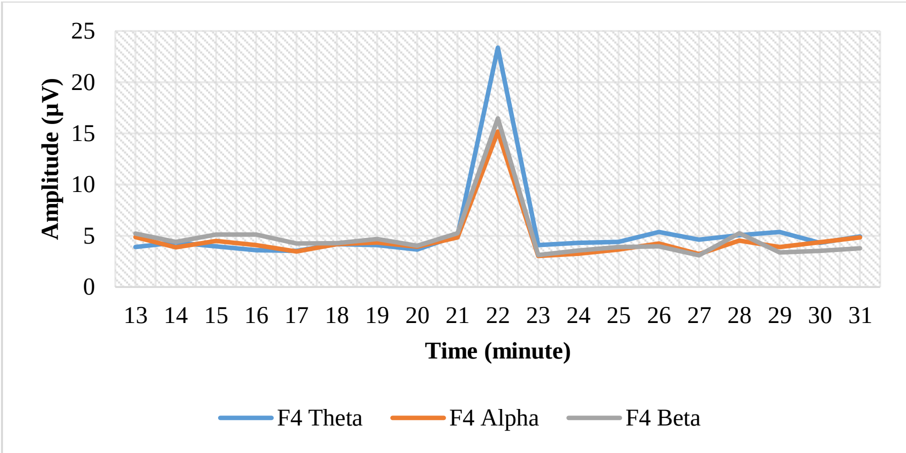


Figure 4.71 RMS Graphic on Respondent 4 at F4 by non-autodidact in the afternoon

Figure 4.72 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the afternoon at P3 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 22nd minute, where the value of Beta, Theta, and Alpha amplitude was 5.2619, 4.2479, and 4.0489 µv at the 22nd minute. Then, the amplitude of Theta and Alpha increased at the 23rd minute where Theta was predominant higher after the 23rd minute. The value of Theta, Alpha, and Beta amplitude at the 23rd minute was 3.7223, 2.8228, and 3.5166 µv.

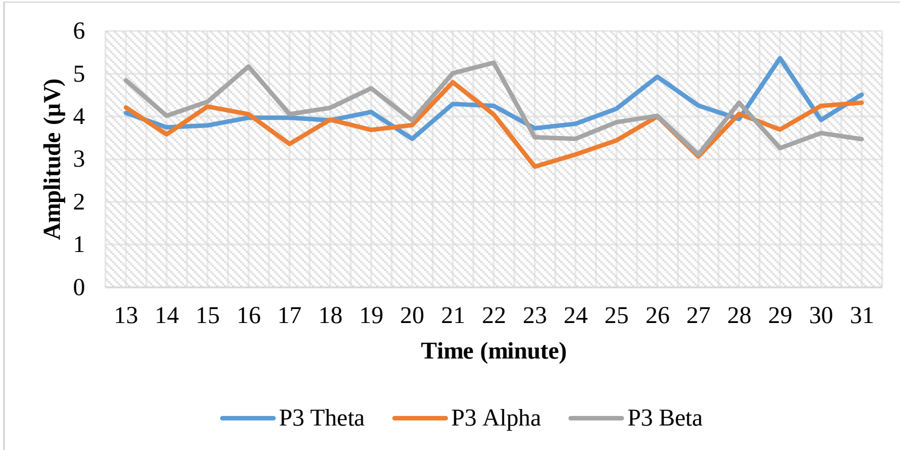


Figure 4.72 RMS Graphic on Respondent 4 at P3 by non-autodidact in the afternoon

Figure 4.73 shows the amplitude RMS graphic of fourth respondent's EEG final signal on non-autodidact in the afternoon at P4 channel. It shows that amplitude of Beta was the greatest compare to Theta and Alpha until at the 21st minute, where the value of Beta, Theta, and Alpha amplitude was 5.9156, 3.881, 5.0525 µv at the 21st minute. Then, the amplitude of Theta and Alpha increased at the 22nd minute where Alpha was predominant higher after 22nd minute. The value of Theta, Alpha, and Beta amplitude at the 22nd minute was 5.8108, 5.0831, and 5.5946 µv.

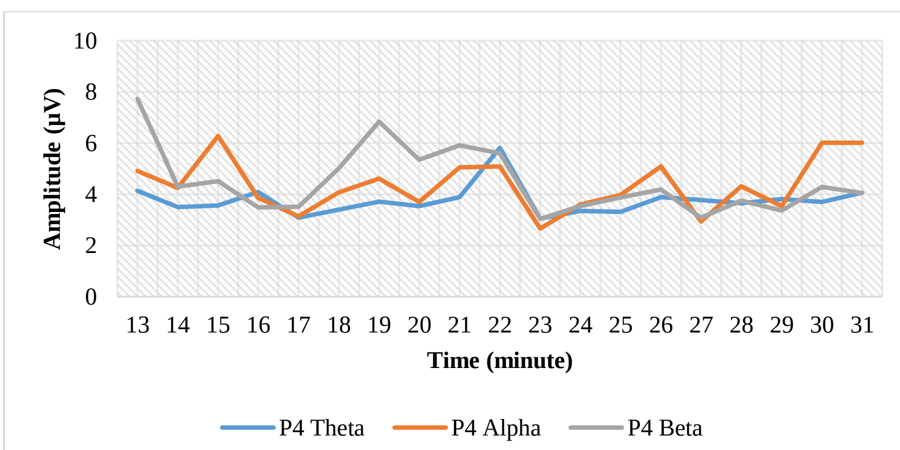


Figure 4.73 RMS Graphic on Respondent 4 at P4 by non-autodidact in the afternoon

Based on Figure 4.70 and Figure 4.71, the ability of respondent 4 to memorize and solve problems appeared until at the 21st minute. Then at the 22nd minute, it decreased and respondent 4 had no concentration and felt sleepy. As well as shown on Figure 4.72 and Figure 4.73, the ability of respondent 4 to read and understand the lesson appeared until at the 22nd minute. Then at the 23rd minute, it decreased and respondent 4 had no concentration and felt sleepy. It indicated that respondent 4 had not focussed on Physics subject at the 23rd minute during studying on non-autodidact in the afternoon.

4.2.3 EARLY TIME FOR THE INCREASING OF THETA AND ALPHA

According to RMS graphic on each respondent at each session, it resulted that early time is considered as a time when respondent has not been focussed. Early time for the Increasing of Theta and Alpha shows in Table 4.3 below.

Table 4.3 Early Time for the Increasing of Theta and Alpha

Respondent	**Autodidact**		**Non-Autodidact**	
	Late Morning (at…minute)	**Afternoon (at…minute)**	**Late Morning (at…minute)**	**Afternoon (at…minute)**
S1	50th	34th	82nd	21st
S2	48th	31st	57th	39th
S3	61st	27th	66th	31st
S4	58th	25th	58th	23rd
Average	**54.25th**	**29.25th**	**65.75th**	**28.5th**

4.2.4 RESULT OF STATISTICAL TEST

4.2.4.1 Wilcoxon Signed Rank Test for Result Final Score

Non-parametric statistical analysis of Wilcoxon Signed Rank test was used to demonstrate the difference between the independent samples of the study. On this study, the independent samples were divided into learning method and condition of result final score. Final score of study was gotten based on the correct answer toward 10 questions offered after each session which shows on Table 4.2 above. The Wilcoxon Signed Rank test was conducted to testify the significant difference between both data.

a. Between late morning and afternoon condition on autodidact learning method

   Based on Table 4.2 that shows the score of Physic subject especially on Electromagnetic Induction subchapter, Wilcoxon Signed Rank test to demonstrate the difference between late morning and afternoon condition on autodidact learning method was conducted. The input for variable 1 is autodidact in the late morning final score data, then variable 2 is autodidact in the afternoon final score data. The output is shown in Table 4.4 below.

Table 4.4 Wilcoxon Signed Rank Test for Result Final Score on Autodidact Learning Method

Result Final Score on Autodidact Learning Method	
Asymp. Sig. (2-tailed)	0.059
Negative Ranks	4
Positive Ranks	0
Ties	0

Based on Table 4.4 above, it is shown that all final score data for autodidact in the afternoon (input variable 2) were lower than autodidact in the morning (input variable 1). Then, the result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed)

> 0.05. It means that result final score on autodidact learning method between late morning and afternoon condition is not significantly different.

b. Between late morning and afternoon condition on non-autodidact learning method
Based on Table 4.2 that shows the score of Physic subject especially on Electromagnetic Induction subchapter, Wilcoxon Signed Rank test to demonstrate the difference between late morning and afternoon condition on non-autodidact learning method was conducted. The input for variable 1 is non-autodidact in the late morning final score data, then variable 2 is non-autodidact in the afternoon final score data. The output is shown in Table 4.5 below.

Table 4.5 Wilcoxon Signed Rank Test for Result Final Score on Non-Autodidact Learning Method

Result Final Score on Non-Autodidact Learning Method	
Asymp. Sig. (2-tailed)	0.102
Negative Ranks	3
Positive Ranks	0
Ties	1

Based on Table 4.5 above, it is shown that 3 final data of non-autodidact in the afternoon (input variable 2) were lower than non-autodidact in the late morning (input variable 1), while remain was ties. The result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed) > 0.05. It means that result final score on non-autodidact learning method between late morning and afternoon condition is not significantly different.

c. Between autodidact and non-autodidact learning method in the late morning condition
Based on Table 4.2 that shows the score of Physic subject especially on Electromagnetic Induction subchapter, Wilcoxon Signed Rank test to demonstrate the difference between late autodidact and non-autodidact learning method in the late morning condition was conducted. The input for variable 1 is autodidact in the

late morning final score data, then variable 2 is non-autodidact in the late morning final score data. The output is shown in Table 4.6 below.

Table 4.6 Wilcoxon Signed Rank Test for Result Final Score in the Late Morning Condition

Result Final Score in the Late Morning Condition	
Asymp. Sig. (2-tailed)	0.109
Negative Ranks	3
Positive Ranks	0
Ties	1

Based on Table 4.6 above, it is shown that 3 final data of non-autodidact in the late morning (input variable 2) were lower than autodidact in the late morning (input variable 1), while remains were ties. The result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed) > 0.05. It means that result final score in the late morning condition between autodidact and non-autodidact learning method is not significantly different.

d. Between autodidact and non-autodidact learning method in the afternoon condition

Based on Table 4.2 that shows the score of Physic subject especially on Electromagnetic Induction subchapter, Wilcoxon Signed Rank test to demonstrate the difference between late autodidact and non-autodidact learning method in the afternoon condition was conducted. The input for variable 1 is autodidact in the afternoon final score data, then variable 2 is non-autodidact in the afternoon final score data. The output is shown in Table 4.7 below.

Table 4.7 Wilcoxon Signed Rank Test for Result Final Score in the Afternoon Condition

Result Final Score in the Afternoon Condition	
Asymp. Sig. (2-tailed)	0.180
Negative Ranks	2
Positive Ranks	0
Ties	2

Based on Table 4.7 above, it is shown that 3 final data of non-autodidact in the afternoon (input variable 2) were lower than autodidact in the afternoon (input variable 1), while remain was ties. The result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed) > 0.05. It means that result final score in the afternoon condition between autodidact and non-autodidact learning method is not significantly different.

4.2.4.2 Wilcoxon Signed Rank Test on Early Time for the Increasing of Theta and Alpha

Non-parametric statistical analysis of Wilcoxon Signed Rank test was used to demonstrate the difference between the independent samples of the study. On this study, the independent samples were divided into learning method and condition on early time for the increasing of Theta and Alpha. Early time for the increasing of Theta and Alpha was gotten from RMS calculation on each respondent at each session that shows at Table 4.3. The Wilcoxon Signed Rank test was conducted to testify the significant difference between both data.

a. Between late morning and afternoon condition on autodidact learning method

   Based on Table 4.3 that shows the early time for the increasing of Theta and Alpha, Wilcoxon Signed Rank test to demonstrate the difference between late morning and afternoon condition on autodidact learning method was conducted. The input for variable 1 is autodidact in the late morning data of early time for increasing theta and alpha, then variable 2 is autodidact in the afternoon data of early time for increasing theta and alpha. The output is shown in Table 4.8 below.

Table 4.8 Wilcoxon Signed Rank Test (Early Time for the Increasing of Theta and Alpha on Autodidact Learning Method)

Early Time for the Increasing of Theta and Alpha on Autodidact Learning Method	
Asymp. Sig. (2-tailed)	0.068
Negative Ranks	4
Positive Ranks	0
Ties	0

Based on Table 4.8 above, it is shown that all of data on autodidact in the afternoon (input variable 2) were lower than autodidact in the late morning data (input variable 1). The result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed) < 0.05. It means that early time for the increasing of Theta and Alpha on autodidact learning method between late morning and afternoon condition is not significantly different.

b. Between late morning and afternoon condition on non-autodidact learning method

Based on Table 4.3 that shows the early time for the increasing of Theta and Alpha, Wilcoxon Signed Rank test to demonstrate the difference between late morning and afternoon condition on non-autodidact learning method was conducted. The input for variable 1 is non-autodidact in the late morning data of early time for increasing theta and alpha, then variable 2 is non-autodidact in the afternoon data of early time for increasing theta and alpha. The output is shown in Table 4.9 below.

Table 4.9 Wilcoxon Signed Rank Test (Early Time for the Increasing of Theta and Alpha on Non-Autodidact Learning Method)

Early Time for the Increasing of Theta and Alpha on Non-Autodidact Learning Method	
Asymp. Sig. (2-tailed)	0.066
Negative Ranks	4
Positive Ranks	0
Ties	0

Based on Table 4.9 above, it is shown that all of data on non-autodidact in the afternoon (input variable 2) were lower than non-autodidact in the afternoon data (input variable 1). The result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed) > 0.05. It means that early time for the increasing of Theta and Alpha on non-autodidact learning method between late morning and afternoon condition is not significantly different.

c. Between autodidact and non-autodidact learning method in the late morning condition

Based on Table 4.3 that shows the early time for the increasing of Theta and Alpha, Wilcoxon Signed Rank test to demonstrate the difference between autodidact and non-autodidact learning method in the late morning condition was conducted. The input for variable 1 is autodidact in the late morning data of early time for increasing theta and alpha, then variable 2 is non-autodidact in the late morning data of early time for increasing theta and alpha. The output is shown in Table 4.10 below.

Table 4.10 Wilcoxon Signed Rank Test (Early Time for the Increasing of Theta and Alpha in the Late Morning Condition)

Early Time for the Increasing of Theta and Alpha in the Late Morning Condition	
Asymp. Sig. (2-tailed)	0.109
Negative Ranks	0
Positive Ranks	3
Ties	1

Based on Table 4.10 above, it is shown that 3 data on non-autodidact in the late morning (input variable 2) were higher than autodidact in the late morning data (input variable 1), while remain was ties. The result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed) > 0.05. It means that early time for the increasing of Theta and Alpha in the late morning condition between autodidact and non-autodidact learning method is not significantly different.

d. Between autodidact and non-autodidact learning method in the afternoon condition

Based on Table 4.3 that shows the early time for the increasing of Theta and Alpha, Wilcoxon Signed Rank test to demonstrate the difference between autodidact and non-autodidact learning method in the afternoon condition was conducted. The input for variable 1 is autodidact in the afternoon data of early time for increasing theta and alpha, then variable 2 is non-autodidact in the afternoon data of early time for increasing theta and alpha. The output is shown in Table 4.11 below.

Table 4.11 Wilcoxon Signed Rank Test (Early Time for the Increasing of Theta and Alpha in the Afternoon Condition)

Early Time for the Increasing of Theta and Alpha in the Afternoon Condition	
Asymp. Sig. (2-tailed)	1.000
Negative Ranks	2
Positive Ranks	2
Ties	0

Based on Table 4.11 above, it is shown that 2 data on non-autodidact in the afternoon (input variable 2) were lower than autodidact in the afternoon data (input variable 1), while remains were the opposite where 2 data on non-autodidact in the afternoon (input variable 2) were higher than autodidact in the afternoon data (input variable 1). The result of Wilcoxon Signed Rank test is Asymp. Sig. (2-tailed) > 0.05. It means that early time for the increasing of Theta and Alpha in the afternoon condition between autodidact and non-autodidact learning method is not significantly different.

CHAPTER V

DISCUSSION

5.1 SINGLE TRIAL

The experiment was conducted for 4 sessions and 1 trial each session. Singe-trial method refers to method that considers the variance within subjects. Based on Pernet et al., (2011), there are two broad families of methods that can be distinguished into univariate methods extract information among trials in space, time, or both; and multivariate methods extract information across space, time, or both, in individual trials. Univariate methods or single trial analyses can help to provide a systematic mapping between (i) brain activity and stimulus information space, (ii) brain activity and subject’s behavioural variability, and (iii) brain activity measured using different imaging techniques.

Based on Pernet et al., (2011), single trial was possible to be done on EEG study. Meanwhile, Chen et al., (2013, 2014) and Zhao et al., (2012) did their experiment using single trial on continues task. Those experiments were done for measuring mental fatigue by recording brain wave using EEG that similar with the experiment design on this research.

5.2 WAVE BRAIN ANALYSIS

The experiment was done by recording the wave brain on Frontal (F3 and F4) and Parietal (P3 and P4) lobes using EEG. Cheng & Hsu (2011) explained that the Frontal lobes have been found to play a part in impulse control, judgment, language production, working memory, motor function, problem solving, sexual behavior, socialization, and spontaneity. Parietal lobe integrates sensory information, specifically dealing with spatial sense and navigation. Another function is the ability for comprehending numbers and the manipulation of objects. This area is responsible for sensation, or the ability of the brain to use senses to detect different environmental entities. Damage to this lobe can cause eyesight problems, left and right hemisphere confusion, inability to perform mathematical solutions, reading and writing problems, and symbol comprehension.

On each lobe, brain waves distinguished by their frequency which Theta, Alpha, and Beta waves. According to Sanei & Chambersm (2007), Theta waves (4-8 Hz) appear as consciousness slips toward drowsiness. Alpha waves (8-13 Hz) had been thought to indicate both a relaxed awareness without any attention or concentration. Beta waves (13-30 Hz) are the usual waking rhythm of the brain associated with active thinking, active attention, focus on the outside world, or solving concrete problems.

Based on the result of amplitude RMS graphic on Frontal (F3 and F4) and Parietal (P3 and P4) lobes by autodidact and non-autodidact in the late morning and afternoon condition, it showed that Beta always had the highest amplitude compare to Theta and Alpha in the beginning time of learning the Physics. Then, in the certain minute, there was a changes of amplitude where amplitude of Theta and/or Alpha increased and higher than amplitude of Beta. It means that the active thinking was happened in the beginning time of learning the Physics whereas the ability to read, understand the lesson, memorize and solve the problems was appeared. Then, on the certain time, those abilities were decreased and the respondent was in a relaxed awareness without any concentration and drowsiness condition.

According to Wascher et al., (2014), mental fatigue of a person during cognitive task was able to indicate when Alpha and Theta rhythms significantly increased, while Beta rhythm significantly decreased in amplitude. It means that a relaxed awareness without any concentration and drowsiness condition that got on a person during cognitive task indicated as mental fatigue state.

5.3 SCORE OF STUDY ANALYSIS

Based on Table 4.2, by autodidact method in the late morning, the result of final score (67.5 of 100) was the highest among others. In the afternoon, the result of final score (52.5 of 100) was lower than the result of final score in the late morning condition. By non-autodidact method in the late morning, the result of final score (52.5 of 100) was higher than the result of final score in the afternoon (50 of 100).

Wilcoxon Signed Rank Test revealed that average score of study between the learning method (autodidact and non-autodidact) and condition (late morning and afternoon) was not significantly different (P > 0.05), which are shown in Table 5.1 below:

Table 5.1 Wilcoxon Signed Rank Test Result on Score of Study

Table	Result	Asymp. Sig
4.4	4 data: Autodidact (afternoon) < Autodidact (late morning)	0.059
4.5	3 data: Non-autodidact (afternoon) < Non-autodidact (late morning) 1 data: Non-autodidact (afternoon) = Non-autodidact (late morning)	0.102
4.6	3 data: Non-autodidact (late morning) < Autodidact (late morning) 1 data: Non-autodidact (late morning) = Autodidact (late morning)	0.109
4.7	2 data: Non-autodidact (afternoon) < Autodidact (afternoon) 2 data: Non-autodidact (afternoon) = Autodidact (afternoon)	0.108

5.4 EARLY TIME FOR GETTING MENTAL FATIGUE

Based on Table 4.3, by autodidact method in the late morning, early time for declining the concentration of respondents started in range between 48 to 61 minutes or at average 54.25 minutes. In the afternoon, respondents started to decline of the concentration in range between 25 to 34 minutes or at average 29.25 minutes. By non-autodidact method in the late morning, early time for declining the concentration of participants started in range between 57 to 82 minutes or at average 65.75 minutes. In the afternoon, respondents started to decline of the concentration in range between 21 to 39 minutes or at average 28.5 minutes. The declining of concentration meant that respondents started to get mental fatigue (Wascher et al., 2014).

Wilcoxon Signed Rank Test revealed that average early time for getting mental fatigue between the learning method (autodidact and non-autodidact) and condition (late morning and afternoon) was not significantly different ($P > 0.05$), which are shown in Table 5.2 below:

Table 5.2 Wilcoxon Signed Rank Test Result on Early Time for Getting Mental Fatigue

Table	**Result**	**Asymp. Sig**
4.8	4 data: Autodidact (afternoon) < Autodidact (late morning)	0.068
4.9	4 data: Non-autodidact (afternoon) < Non-autodidact (late morning)	0.066
4.10	3 data: Non-autodidact (late morning) > Autodidact (late morning) 1 data: Non-autodidact (late morning) = Autodidact (late morning)	0.109
4.11	2 data: Non-autodidact (afternoon) < Autodidact (afternoon) 2 data: Non-autodidact (afternoon) > Autodidact (afternoon)	1.000

5.5 CONDITION VARIABLE ANALYSIS

As the experiment that has been done, there was a variable about conditions which are late morning and afternoon condition. Based on Table 5.1 about score of study statistical test result and Table 5.2 about time for respondent reached a mental fatigue statistical test result, late morning condition was better in score of study and longer in time for getting mental fatigue than afternoon condition.

Slameto (2013) expressed that student had fresher mind and a better physical condition in earlier day compared to the student’s condition in the afternoon. It is stated that a student will find it more difficult in receiving information in the afternoon due to the exhausted body condition. Vollmer et al., (2013) also stated that morning method person in learning style gets both better grading and higher attention.

Moreover, it was noted that the experiment performed in the late morning showed 26.7˚C as the room temperature, and 31.9 ˚C in the afternoon experiment. Kulve et al., (2017) mentioned that the sleepiness of a person is significantly higher while reaction time is slower in warm exposure. Romeijn et al., (2012) expressed that alertness will reduce when room temperatures increases; while Lan et al., (2011) stated that a high ambient temperature could reduce the performance on reaction time tasks. Thus, based on room temperature, previous study was in line with the experiment result, where the room temperature of afternoon experiment was warmer than the one in the late morning experiment and went along with the fastest time in starting mental fatigue.

In addition, the lighting level of late morning experiment (79 Lux) was brighter than afternoon experiment (70 Lux) resulting in a longer time in starting mental fatigue in the late morning. It was approved by Romeijn et al., (2012) that bright light could reduce the sleepiness and improve a task performance. So that, learning process in the late morning had better performance based on score of study and early time for getting mental fatigue result.

5.6 LEARNING TYPE VARIABLE ANALYSIS

Another variable is learning types which are autodidact and non-autodidact learning type. Based on Table 4.2 and Table 4.3, it can be summarized that in the late morning:

a. By autodidact learning type, the early time for getting mental fatigue was 54.25^{th} minute with result score of study was 67.5 of 100.
b. By non-autodidact learning type, the early time for getting mental fatigue was 65.75^{th} minute with result score of study was 52.5 of 100.

Based on that, in the late morning, autodidact learning type had shorter early time for getting mental fatigue than non-autodidact learning type. On the contrary, autodidact learning type had higher result final score then non-autodidact learning type.

Based on Van Oers (1987) in Simons (1989), there are two aspects of student activities during learning, which are quality and quantity of learning activities. Quality of learning activities is quality of information that students got while quantity of learning activities is an effort to get the information during studying. Quality of learning activities in the late morning can be seen by the result score of study gotten where autodidact learning type had higher result final score interpret as better quality of learning activities then non-autodidact learning type with significant difference as much as P=0.109. Moreover, Based on Simons (1989), a student who decided to learn by autodidact learning type have to exert more effort. Meanwhile, based on Babiloni (2012), the more demanding task that needed more effort result higher mental fatigue. It was in line with the result of early time for getting mental fatigue in the late morning, where autodidact learning type needed more effort resulted more earlier time for getting mental fatigue than non-autodidact learning type with significant difference as much as P=0.109 for early time mental fatigue comparison.

Meanwhile, based on Table 4.2 and Table 4.3, it can be summarized that in the afternoon condition:

a. By autodidact learning type, the early time for getting mental fatigue was 29.25^{th} minute with result score of study was 52.5 of 100.
b. By non-autodidact learning type, the early time for getting mental fatigue was 28.25^{th} minute with result score of study was 40 of 100.

It can be seen that autodidact learning type has longer early time for getting mental fatigue and higher result score of study than non-autodidact learning type in the afternoon with significant difference as much as P=1.000 for both early time mental fatigue and P=0.108 for result score of study comparison.

Furthermore, based on Lodewijks (1982), science student in autodidact learning type is performed better than student in a learning sequence predetermined by teachers and Van der Sanden (1986) in Simons (1989) stated that some students performed better on a practical construction task without instruction than with detailed and explicit advice from a teacher. So that, autodidact learning type had better performance based on early time mental fatigue and score of study result.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

After conducting the study, it can be conclude that:

1. Based on the result of amplitude RMS graphic on Frontal (F3 and F4) and Parietal (P3 and P4) lobes by autodidact and non-autodidact in the late morning and afternoon condition, it showed that Beta wave always had the highest amplitude compare to Theta and Alpha wave in the beginning time of learning the Physics. Then, in the certain minute, there was a change of amplitude where amplitude of Theta and/or Alpha wave increased and higher than amplitude of Beta wave.

2. Mental fatigue while studying Physics with

   a. Autodidact learning method in the late morning is started at the 54.25th minutes with average score of study is 67.5 of 100.
   b. Autodidact learning method in the afternoon is started at the 29.25th minutes with average score of study is 52.5 of 100.
   c. Non-autodidact learning method in the late morning is started at the 65.75th minutes with average score of study is 52.5 of 100.

d. Non-autodidact learning method in the afternoon is started at the 28.5^{th} minutes with average score of study is 40 of 100.

Thus, it can be concluded that the autodidact learning method in the late morning is better in learning the Physics subject.

6.2 RECOMMENDATION

The suggestion that can be given from the results of this research for the company and further researches are:

1. Student could study the Physics by autodidact in the late morning for less than 54.25 minutes, autodidact in the afternoon for less than 29.25 minutes, non-autodidact in the late morning for less than 65.75 minutes, and non-autodidact in the afternoon for less than 28.5 minutes to prevent getting mental fatigue.
2. School could put the Physics subject in the late morning for the school's schedule to get better performance in teaching and learning activities.
3. It is better for student to study using autodidact learning type for better quantity and quality of learning activities.
4. The future study needs to be improved by expanding the comparative study to another learning method and condition. Considering other place outside Bantul for research sample data is also suggested to be investigated.

BIBLIOGRAPGY

Ariani, D. N. (2009). *Tinjauan Faktor-Faktor yang Mempengaruhi Tingkat (Fatigue) pada Pengemudi Bulk truck PT. BCS Subkontraktor PT. Holcim Indonesia Tbk Plant Narogong Tahun 2009*.

Arnau, S., Möckel, T., & Rinkenauer, G. (2017). The interconnection of mental fatigue and aging: An EEG study. *International Journal of Psychophysiology*. https://doi.org/10.1016/j.ijpsycho.2017.04.003

Atmaji, C., & Perwira, Z. Y. (2017). Pengaruh Latar Belakang Warna pada Objek Gambar terhadap Hasil Ekstraksi Sinyal EEG 1. *IJEIS*, *7*(2), 161–172.

Babiloni, F. (2012). Measuring neurophysiological signals in aircraft pilots and car drivers for the assessment of mental workload ... *Neuroscience and Biobehavioral Reviews*, (October). https://doi.org/10.1016/j.neubiorev.2012.10.003

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research*, *25*(1), 107–116. https://doi.org/10.1016/j.cogbrainres.2005.04.011

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action monitoring. *Biological Psychology*, *72*(2), 123–132. https://doi.org/10.1016/j.biopsycho.2005.08.007

Charbonnier, S., Roy, R. N., Bonnet, S., & Campagne, A. (2016). EEG index for control operators' mental fatigue monitoring using interactions between brain regions. *Expert Systems With Applications*. https://doi.org/10.1016/j.eswa.2016.01.013

Chen, C., Li, K., Wu, Q., Wang, H., Qian, Z., & Sudlow, G. (2013). EEG-based detection and evaluation of fatigue caused by watching 3DTV. *Displays*, *34*(2), 81–88. https://doi.org/10.1016/j.displa.2013.01.002

Chen, C., Wang, J., Li, K., Wu, Q., Wang, H., Qian, Z., & Gu, N. (2014). Assessment visual fatigue of watching 3DTV using EEG power spectral parameters. *Displays*, *35*(5), 266–272. https://doi.org/10.1016/j.displa.2014.10.001

Cheng, S.-Y., & Hsu, H.-T. (2011). Mental Fatigue Measurement Using EEG.

Djemari, & Kartowagiran, B. K. (2009). *Dampak Ujian Nasional*. Universitas Negeri Yogyakarta.

Dunn, R., Beaudry, J. S., & Klavas, A. (2002). Survey of Research on Learning Styles. *California Journal of Science Education*, *II*(2), 75–98.

Handayani, S., & Damari, A. (2009). *Fisika untuk SMA dan MA kelas XII*. Jakarta: Pusat Perbukuan, Departemen Pendidikan Nasional.

Herwig, U., Satrapi, P., & Schönfeldt-lecuona, C. (2003). Using the International 10-20 EEG System for Positioning of Transcranial Magnetic Stimulation. *Brain Topography*, *16*(2), 95–99. https://doi.org/10.1023/B

Jaehne, A., Unbehaun, T., Feige, B., Lutz, U. C., Batra, A., & Riemann, D. (2012). How smoking affects sleep: A polysomnographical analysis. *Sleep Medicine*, *13*(10), 1286–1292. https://doi.org/10.1016/j.sleep.2012.06.026

Jason, L. A., Brown, M., Jason, L. A., Evans, M., Brown, M., & Porter, N. (2010). What is Fatigue ? Pathological and Nonpathological Fatigue Fatigue. *PMRJ*, *2*(5), 327–331. https://doi.org/10.1016/j.pmrj.2010.03.028

Kamaliana, N., Deros, B. M., Schramm, D., Hesse, B., Nuawi, M. Z., & Ismail, F. R. (2016). SUBJECTIVE AND INDIRECT METHODS TO OBSERVE DRIVER ' S DROWSINESS AND ALERTNESS : AN OVERVIEW. *Journal of Engineering Science and Technology*, 28–39.

Käthner, I., Wriessnegger, S. C., Müller-putz, G. R., Kübler, A., & Halder, S. (2014). Effects of mental workload and fatigue on the P300 , alpha and theta band power during operation of an ERP (P300) brain – computer interface. *Biological Psychology*, *102*, 118–129. https://doi.org/10.1016/j.biopsycho.2014.07.014

Kim, J. H., & Duffy, J. F. (2018). Circadian Rhythm Sleep-Wake Disorders in Older

Adults. *Sleep Medicine Clinics*, *13*(1), 39–50. https://doi.org/10.1016/j.jsmc.2017.09.004

Kinantie, O. A., Hernawaty, T., & Hidayati1, N. O. (2012). Gambaran tingkat stres siswa SMAN 3 Bandung kelas XII menjelang ujian nasional 2012, 1–14.

Kurniawati, D. (2013). Pentingnya pendidikan bagi semua orang. Retrieved July 24, 2017, from http://www.bunghatta.ac.id/artikel-259-pentingnya-pendidikan-bagi-semua-orang.html

Lan, L., Wargocki, P., & Lian, Z. (2011). Quantitative measurement of productivity loss due to thermal discomfort. *Energy and Buildings*, *43*(5), 1057–1062. https://doi.org/10.1016/j.enbuild.2010.09.001

Li, G., Wang, S., & Duan, Y. Y. (2016). Towards gel-free electrodes: A systematic study of electrode-skin impedance. *Sensors & Actuators: B. Chemical*. https://doi.org/10.1016/j.snb.2016.10.005

Lodewijks, H. G. L. C. (1982). Self-Regulated versus Teacher Provided Sequencing of Information in Learning from Text. *Advances in Psychology*, *8*, 509–520. https://doi.org/10.1016/S0166-4115(08)62715-6

Manuaba, A. (2000). Ergonomi, kesehatan dan keselamatan kerja. In *Proceeding Seminar Nasional Ergonomi*. Surabaya.

Milar, M. (2012). Measuring Fatigue. *Asia-Pacific FRMS Seminar*.

Ministry of Education and Culture. (2017). Rekap Hasil Ujian Nasional (UN) Tingkat Sekolah. Retrieved from https://puspendik.kemdikbud.go.id/hasil-un/

Mun, S., Kim, E., & Park, M. (2014). Effect of mental fatigue caused by mobile 3D viewing on selective attention: An ERP study. *International Journal of Psychophysiology*. https://doi.org/10.1016/j.ijpsycho.2014.08.1389

NASA. (1986). *NASA Task Load Index User Manual v. 1.0*. https://doi.org/10.293994-13

National Sleep Foundation. (2008). How much sleep do we really need. Retrieved from https://sleepfoundation.org/

Pernet, C. R., Sajda, P., & Rousselet, G. A. (2011). Single-trial analyses: Why bother? *Frontiers in Psychology*, *2*(NOV), 1–2. https://doi.org/10.3389/fpsyg.2011.00322

Ream, E., Sc, M., Hons, B. S., Richardson, A., Ph, D., Sc, M., & Hons, B. N. (1996). Fatigue : a concept analysis, *33*(5), 519–529.

Rodahl, K. (1989). *The physiology of Work*. Great Britain: Taylor & Francis Ltd.

Romeijn, N., Raymann, R. J. E. M., Møst, E., Te Lindert, B., Van Der Meijden, W. P., Fronczek, R., … Van Someren, E. J. W. (2012). Sleep, vigilance, and thermosensitivity. *Pflugers Archiv European Journal of Physiology*, *463*(1), 169–176. https://doi.org/10.1007/s00424-011-1042-2

Roy, R. N., Charbonnier, S., & Bonnet, S. (2014). Eye blink characterization from frontal EEG electrodes using source separation and pattern recognition algorithms. *Biomedical Signal Processing and Control*, *14*, 256–264. https://doi.org/10.1016/j.bspc.2014.08.007

Sanei, S., & Chambers, J. (2007). *EEG Signal Processing*. England: John Wily & Sons Ltd.

Shen, J., Barbera, J., & Shapiro, C. M. (2006). Distinguishing sleepiness and fatigue: Focus on definition and measurement. *Sleep Medicine Reviews*, *10*(1), 63–76. https://doi.org/10.1016/j.smrv.2005.05.004

Sibejo. (2016). *Induksi Elektromagnetik*. Retrieved from https://www.youtube.com/user/sibejoo

Simons, P. R. J. (1989). *Learning to learn*. *Triburg University*. Retrieved from http://igitur-archive.library.uu.nl/ivlos/2005-0622-185541/5888.pdf

Slameto. (2013). *Belajar dan faktor-faktor yang mempengaruhinya*. Jakarta: PT Rineka Cipta.

Soewardi, H., Anugraheni, A. R., & Shabrina, N. (2015). Analysis of Electromyography on Computer Interaction Devices to the Risk of Carpal Tunnel Syndrome.

https://doi.org/10.17706/jcp.10.5.3

Sutrisno, A. N. (2012). *Telaah Filsafat Pendidikan*. Yogyakarta: Deepublish. Retrieved from https://books.google.co.id/books?id=iyw8DAAAQBAJ&pg=PA56&dq=pendidikan+adalah&hl=id&sa=X&ved=0ahUKEwi1-de1kKLVAhWCoJQKHcftAeUQ6AEILzAD#v=onepage&q=pendidikan adalah&f=true

te Kulve, M., Schlangen, L. J. M., Schellen, L., Frijns, A. J. H., & van Marken Lichtenbelt, W. D. (2017). The impact of morning light intensity and environmental temperature on body temperatures and alertness. *Physiology and Behavior*, *175*(March), 72–81. https://doi.org/10.1016/j.physbeh.2017.03.043

Van Beek, J. A., De Jong, F. P. C. M., Minnaert, A. E. M. G., & Wubbels, T. (2014). Teacher practice in secondary vocational education: Between teacher-regulated activities of student learning and student self-regulation. *Teaching and Teacher Education*, *40*, 1–9. https://doi.org/10.1016/j.tate.2014.01.005

Vollmer, C., Pötsch, F., & Randler, C. (2013). Morningness is associated with better gradings and higher attention in class. *Learning and Individual Differences*, 1–7. https://doi.org/10.1016/j.lindif.2013.09.001

Wascher, E., Rasch, B., S??nger, J., Hoffmann, S., Schneider, D., Rinkenauer, G., … Gutberlet, I. (2014). Frontal theta activity reflects distinct aspects of mental fatigue. *Biological Psychology*, *96*(1), 57–65. https://doi.org/10.1016/j.biopsycho.2013.11.010

Wilcoxon, F. (1946). Individual Comparisons of Grouped Data by Ranking Methods. *Journal of Economic Entomology*, *39*(2), 269–270. https://doi.org/10.1093/jee/39.2.269

Yin, Z., & Zhang, J. (2017). Cross-session classification of mental workload levels using EEG and an adaptive deep learning model. *Biomedical Signal Processing and Control*, *33*, 30–47. https://doi.org/10.1016/j.bspc.2016.11.013

Zhao, C., Zhao, M., Liu, J., & Zheng, C. (2012). Electroencephalogram and electrocardiograph assessment of mental fatigue in a driving simulator. *Accident Analysis and Prevention*, *45*, 83–90. https://doi.org/10.1016/j.aap.2011.11.019

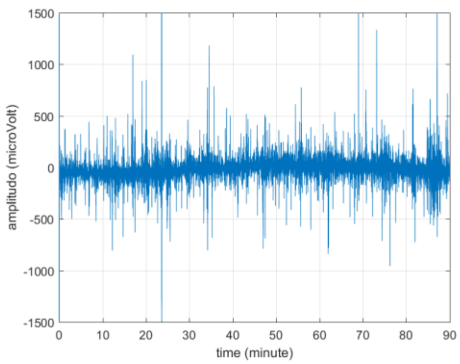
Zimmerman, B. J. (1989). A Social Cognitive View of Self-Regulated Academic Learning. *Journal of Education Psychology*, *81*(3), 1–23.

APPENDICE 1

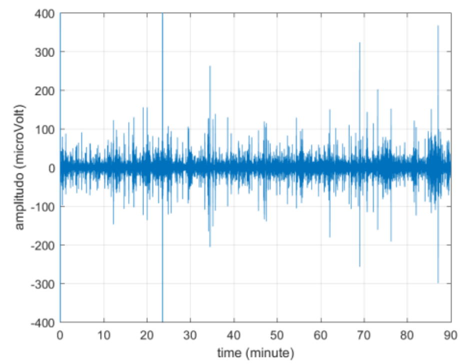
AUTODIDACT IN THE LATE MORNIG [PARTICIPANT 1]

1. F3 channel

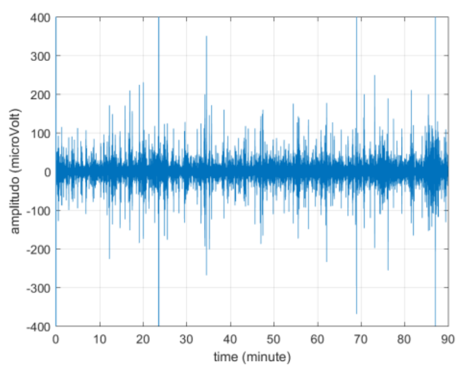
a. EEG Signal



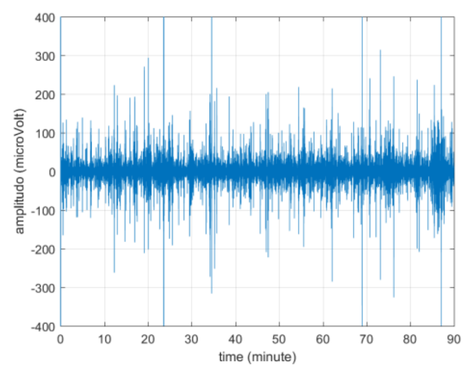
EEG Raw Data



Theta (4-8 Hz)

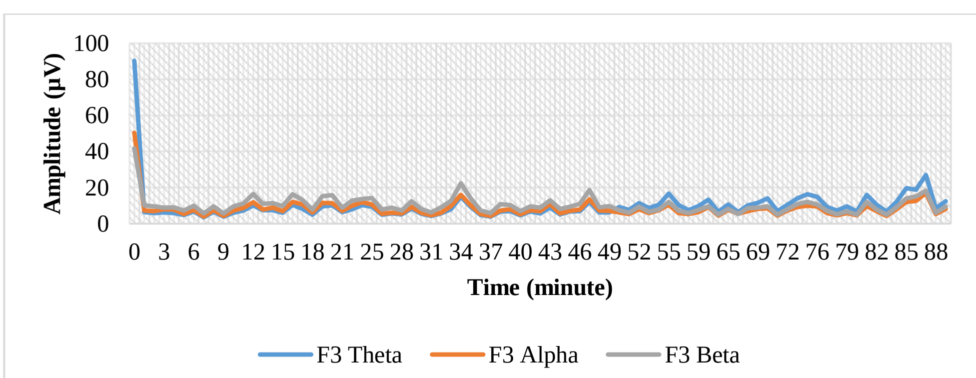


Alpha (8-13 Hz)



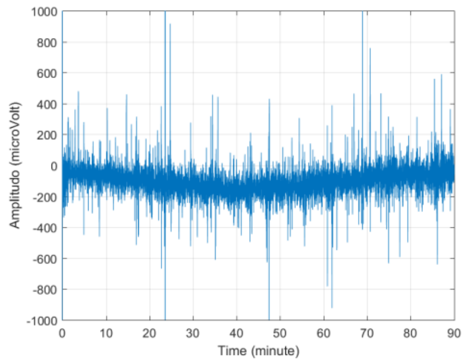
Beta (13-30 Hz)

b. RMS graphic – full time

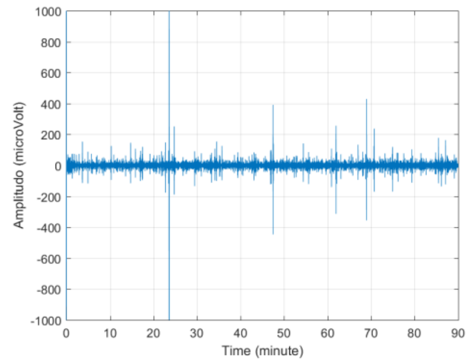


2. F4 channel

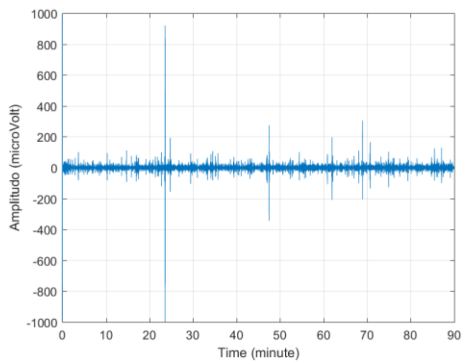
a. EEG Signal



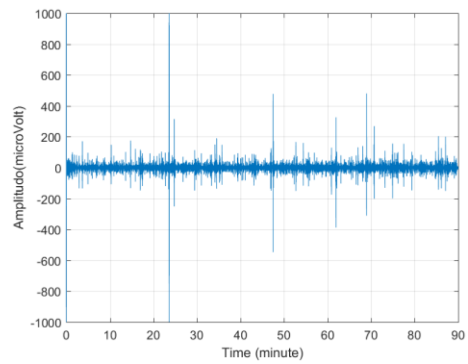
EEG Raw Data



Theta (4-8 Hz)

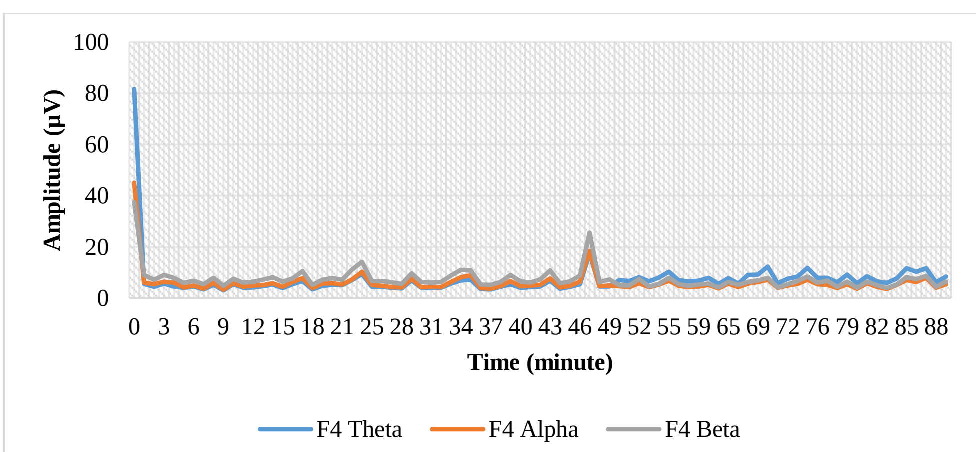


Alpha (8-13 Hz)



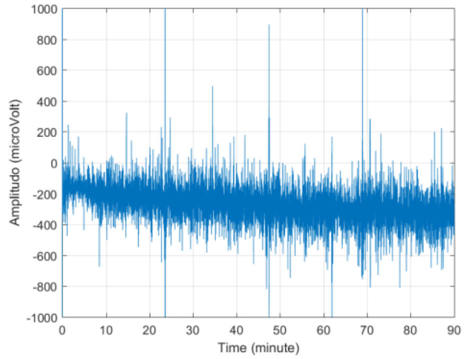
Beta (13-30 Hz)

b. RMS calculation

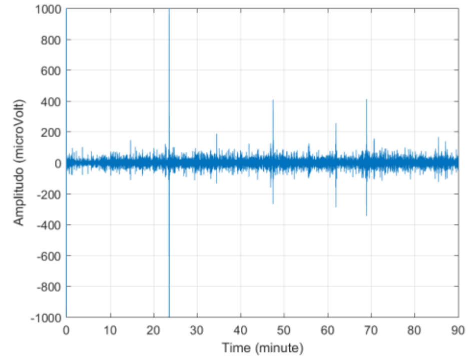


3. P3 channel

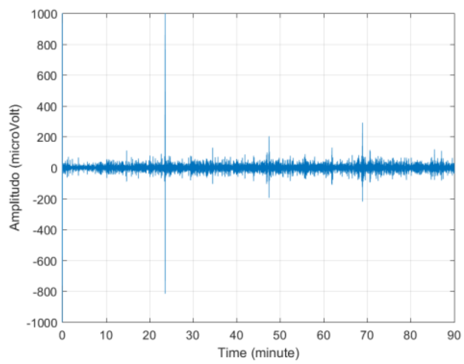
a. EEG Signal



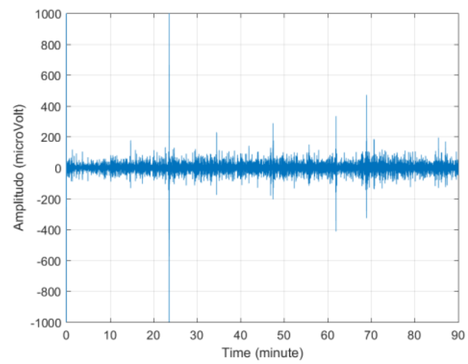
EEG Raw Data



Theta (4-8 Hz)

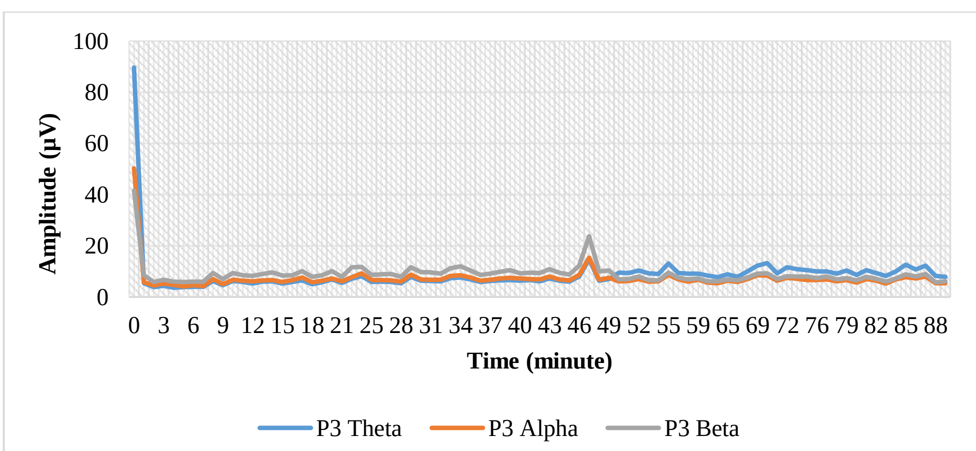


Alpha (8-13 Hz)



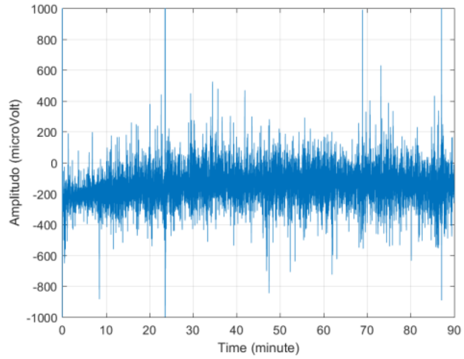
Beta (13-30 Hz)

b. RMS calculation

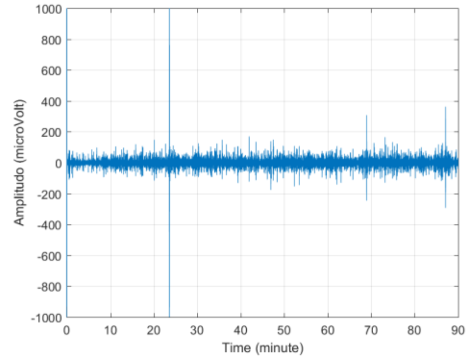


4. P4 channel

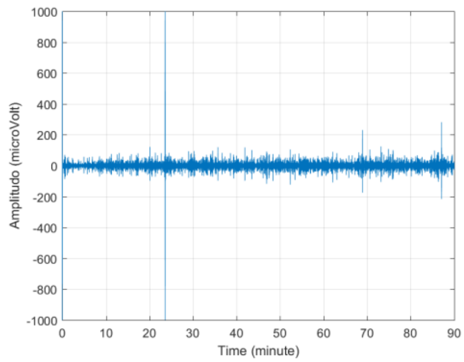
a. EEG Signal



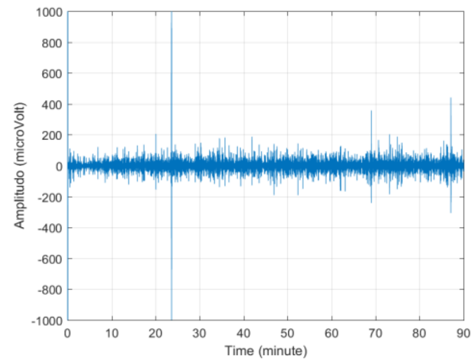
EEG Raw Data



Theta (4-8 Hz)

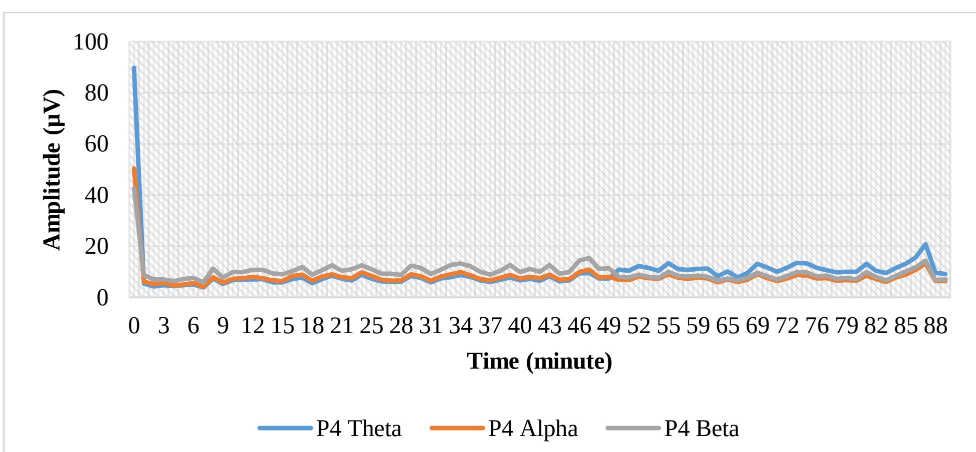


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

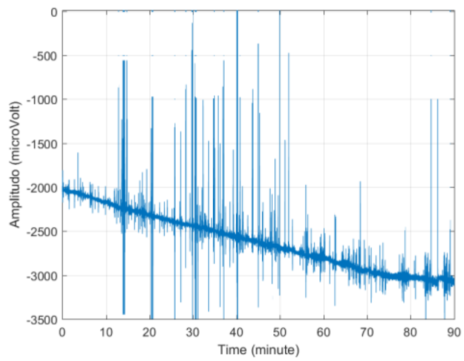


APPENDICES 2

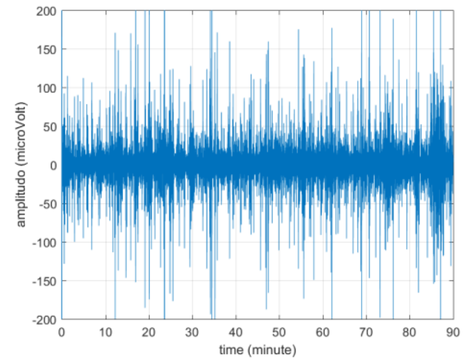
AUTODIDACT IN THE LATE MORNING [PARTICIPANT 2]

1. F3 channel

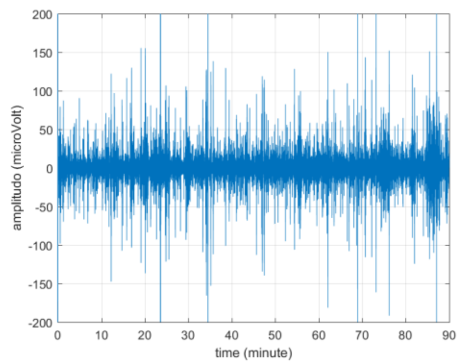
   a. EEG Signal



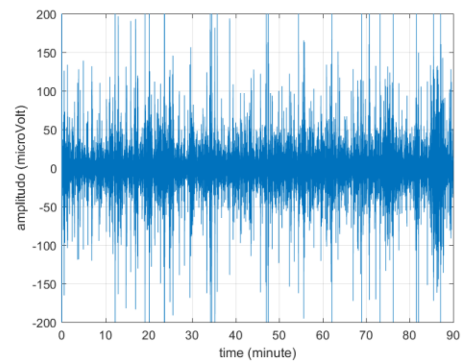
EEG Raw Data



Theta (4-8 Hz)

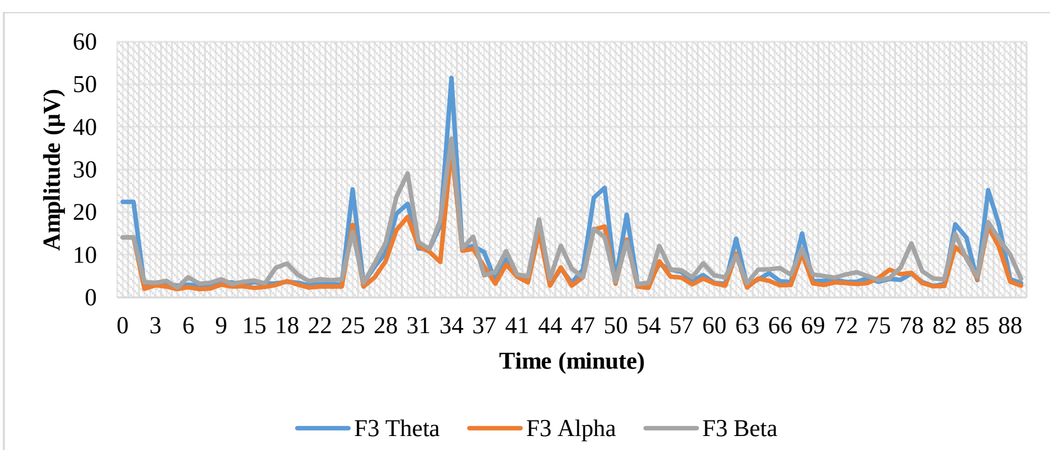


Alpha (8-13 Hz)



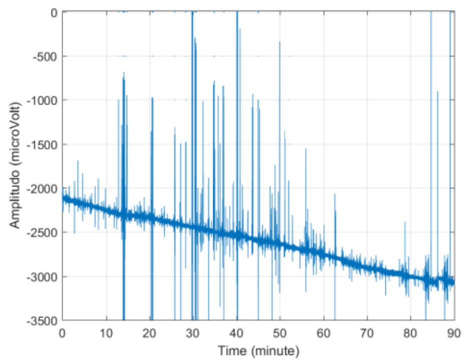
Beta (13-30 Hz)

   b. RMS calculation

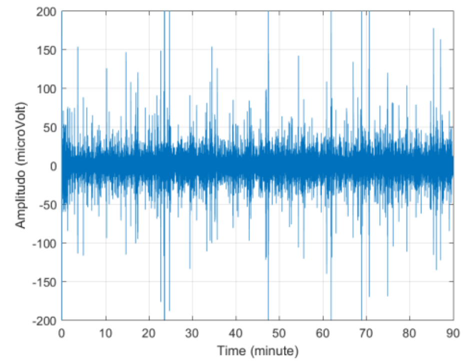


2. F4 channel

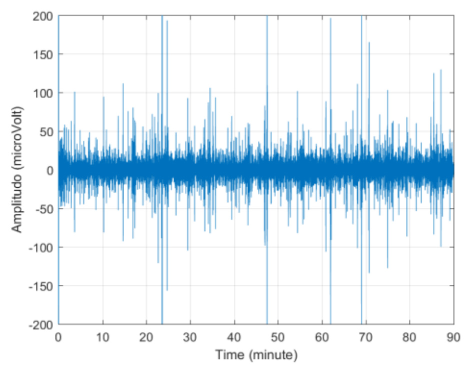
a. EEG Signal



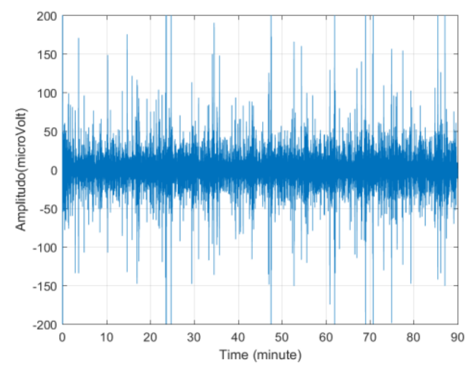
EEG Raw Data



Theta (4-8 Hz)

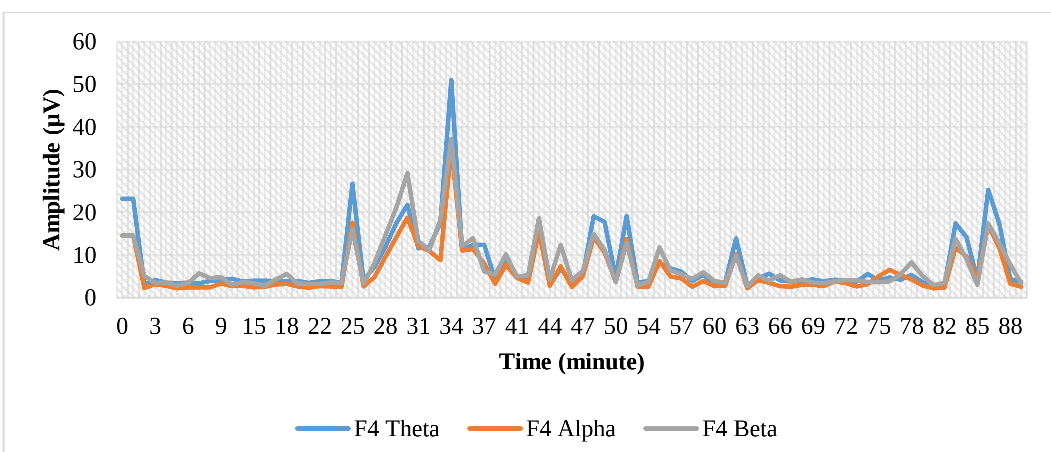


Alpha (8-13 Hz)



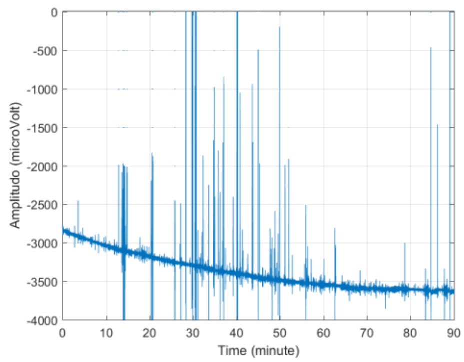
Beta (13-30 Hz)

b. RMS calculation

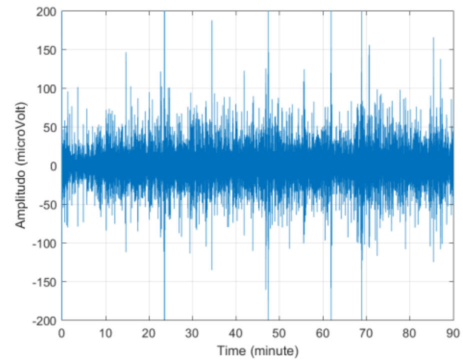


3. P3 channel

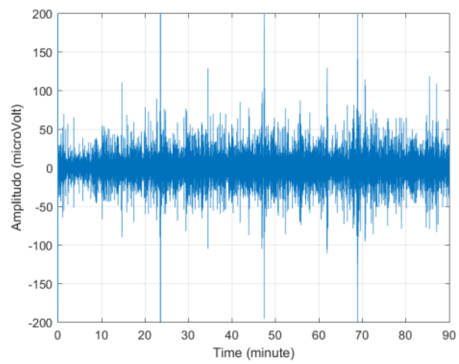
a. EEG Signal



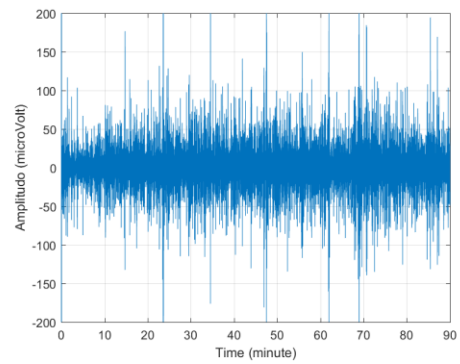
EEG Raw Data



Theta (4-8 Hz)

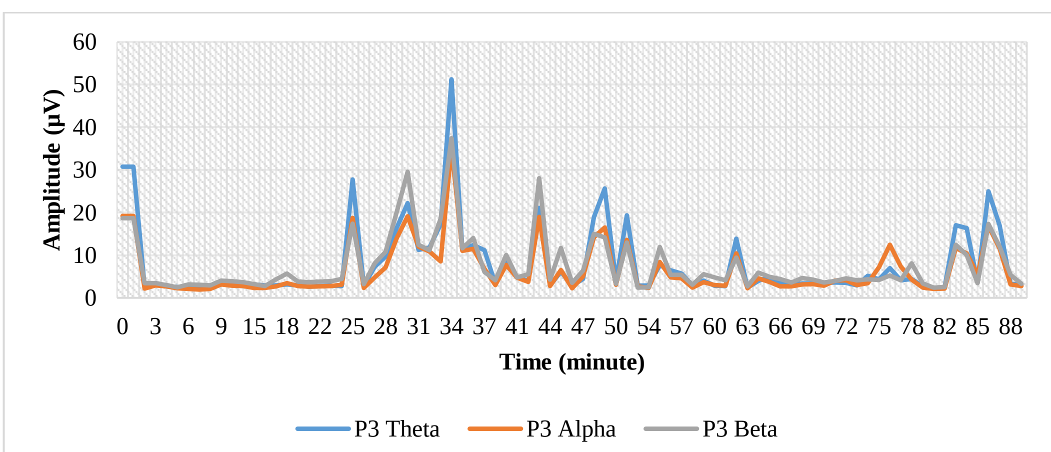


Alpha (8-13 Hz)



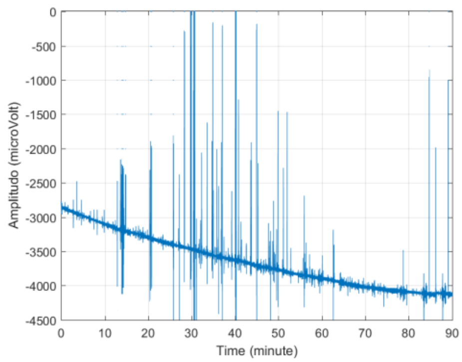
Beta (13-30 Hz)

b. RMS calculation

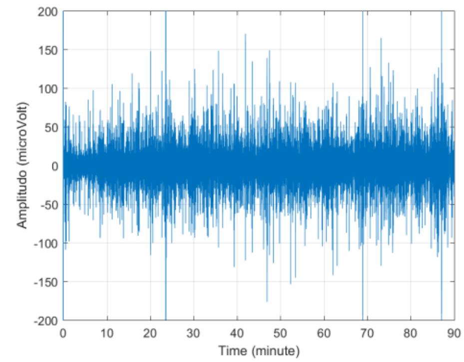


4. P4 channel

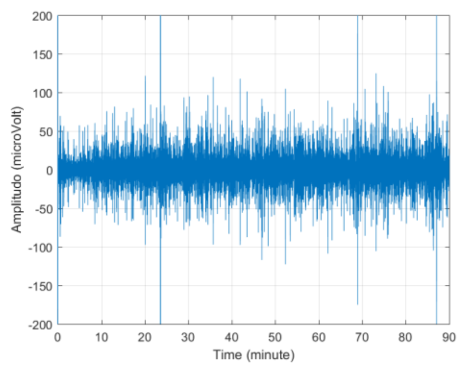
a. EEG Signal



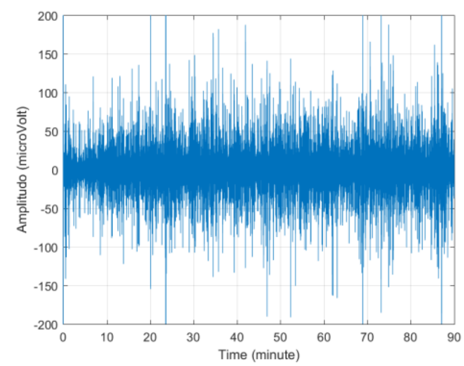
EEG Raw Data



Theta (4-8 Hz)

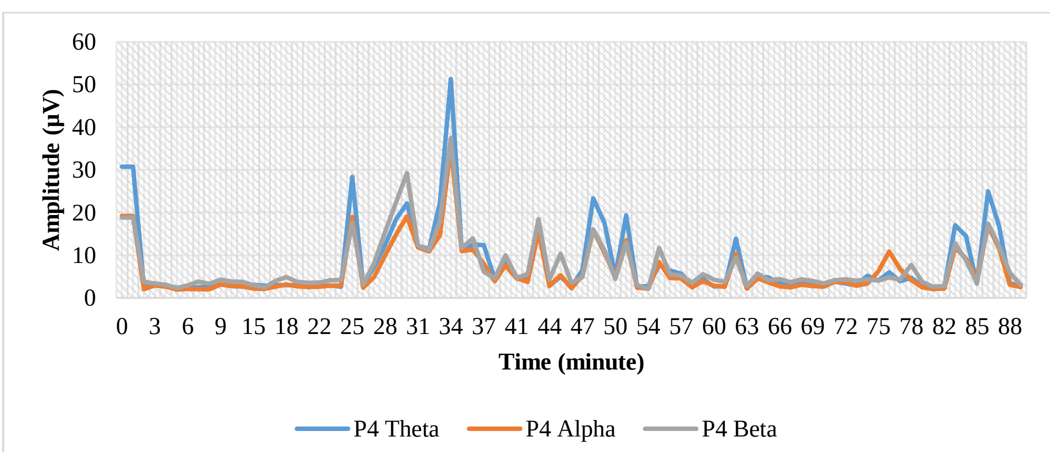


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

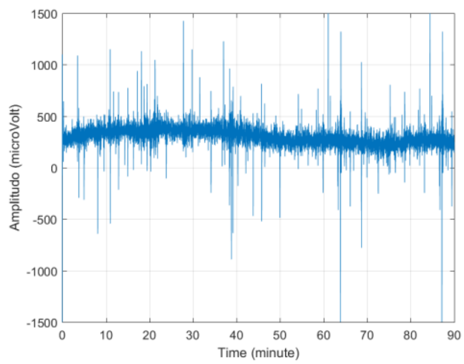


APPENDICES 3

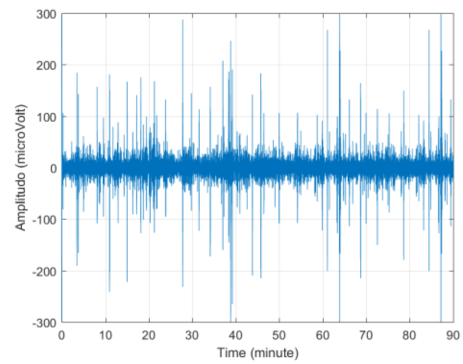
AUTODIDACT IN THE LATE MORNING [PARTICIPANT 3]

1. F3 channel

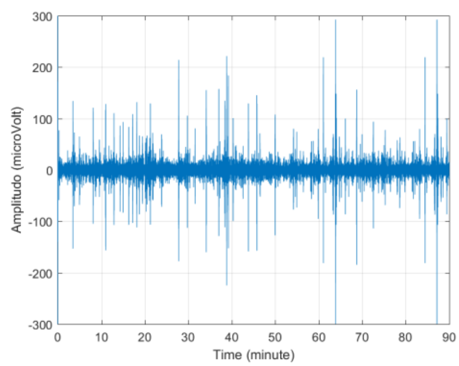
a. EEG Signal



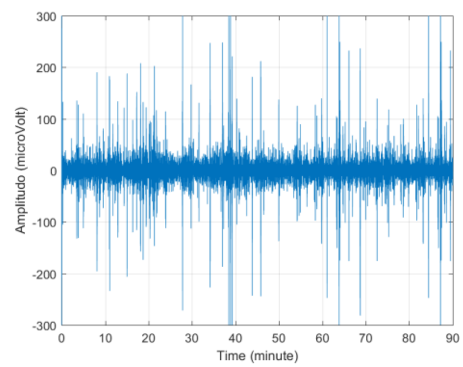
EEG Raw Data



Theta (4-8 Hz)

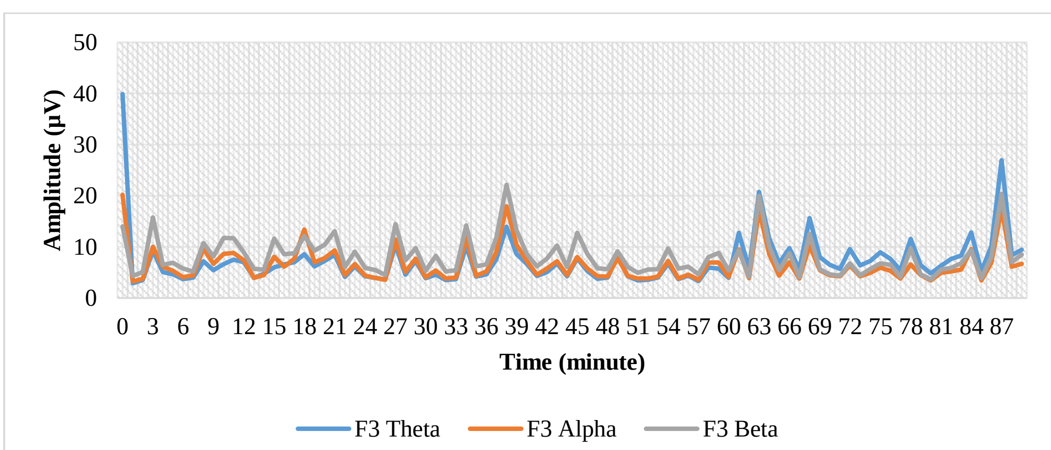


Alpha (8-13 Hz)



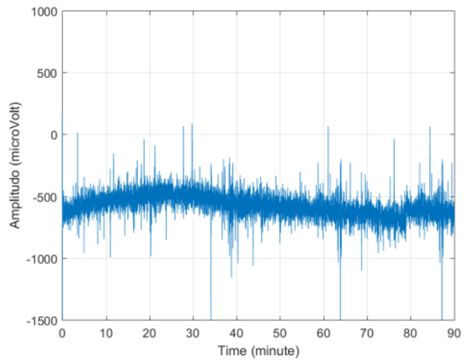
Beta (13-30 Hz)

b. RMS calculation

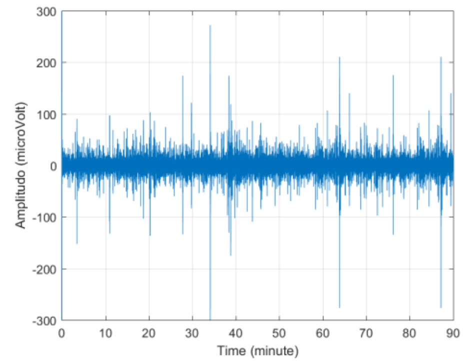


2. F4 channel

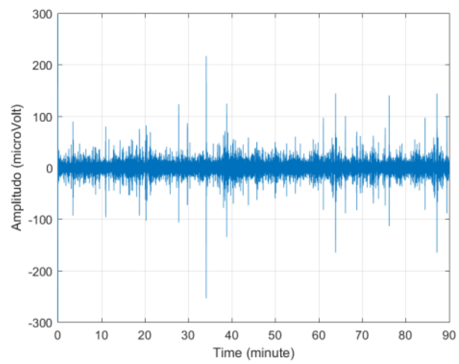
a. EEG Signal



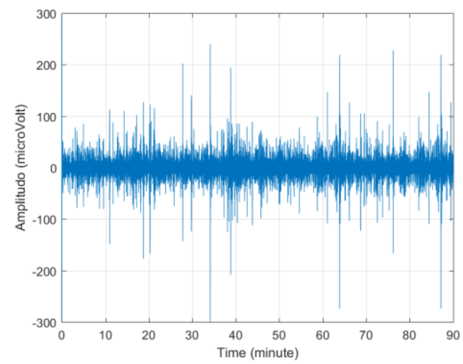
EEG Raw Data



Theta (4-8 Hz)

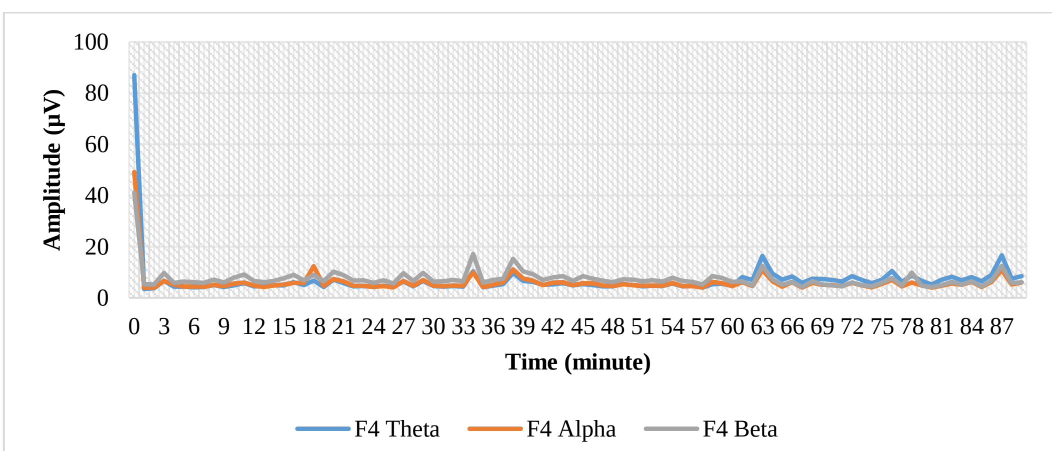


Alpha (8-13 Hz)



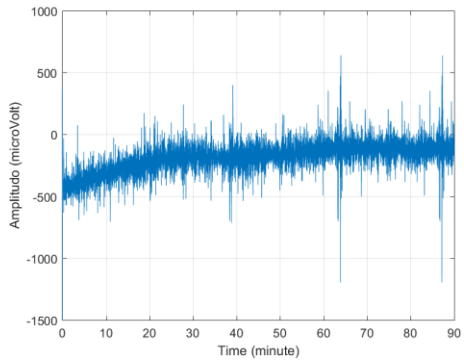
Beta (13-30 Hz)

b. RMS calculation

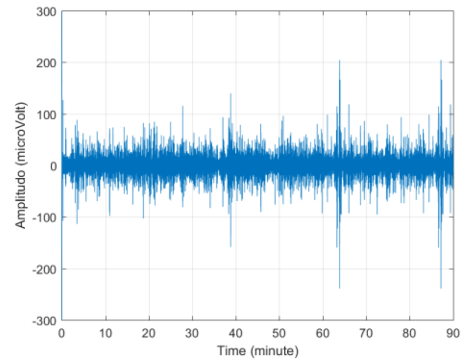


3. P3 channel

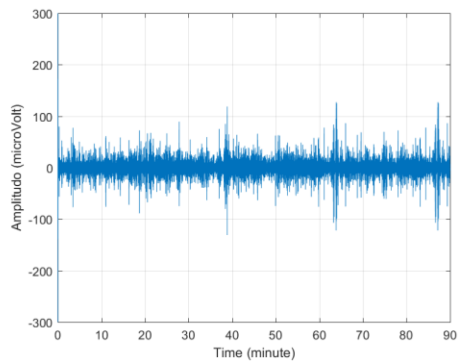
a. EEG Signal



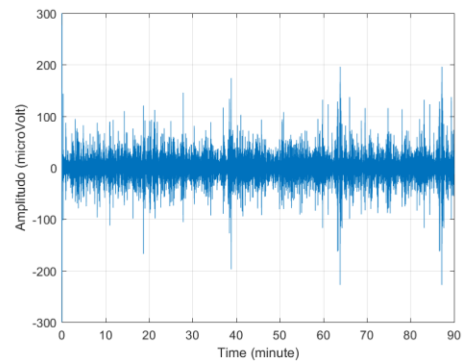
EEG Raw Data



Theta (4-8 Hz)

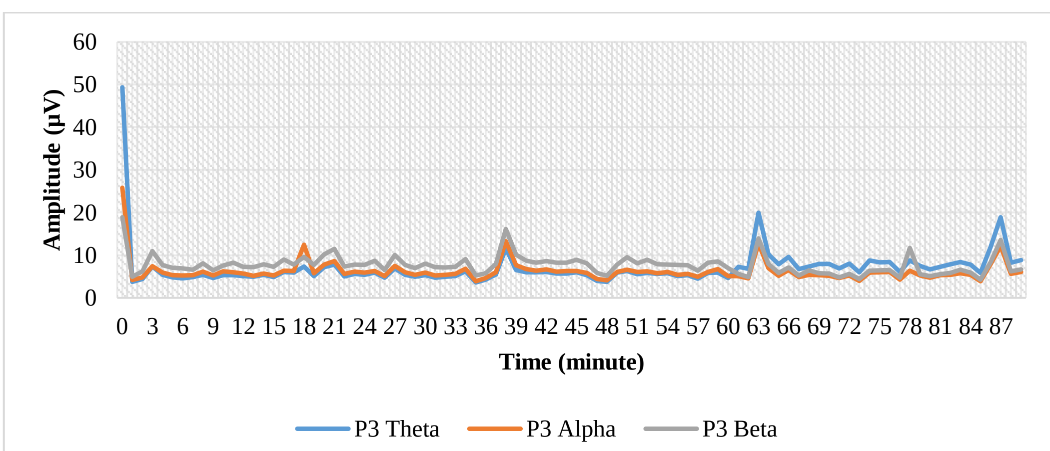


Alpha (8-13 Hz)



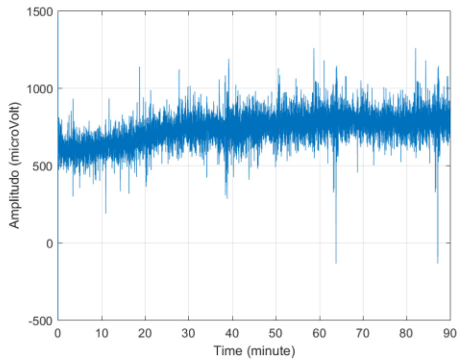
Beta (13-30 Hz)

b. RMS calculation

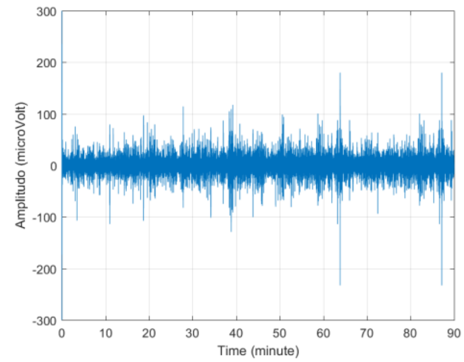


4. P4 channel

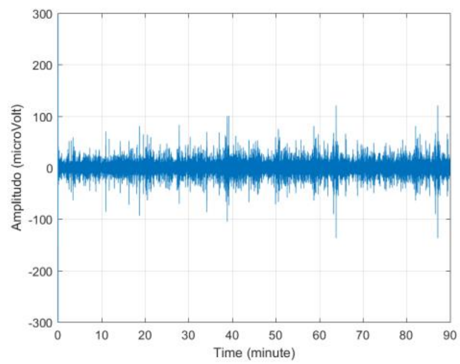
a. EEG Signal



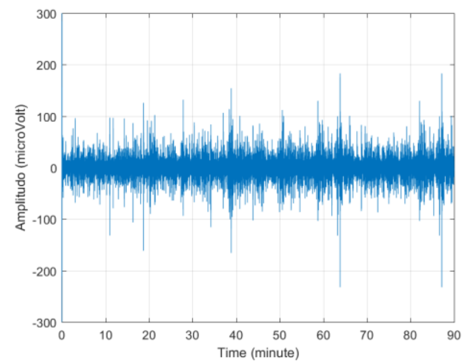
EEG Raw Data



Theta (4-8 Hz)

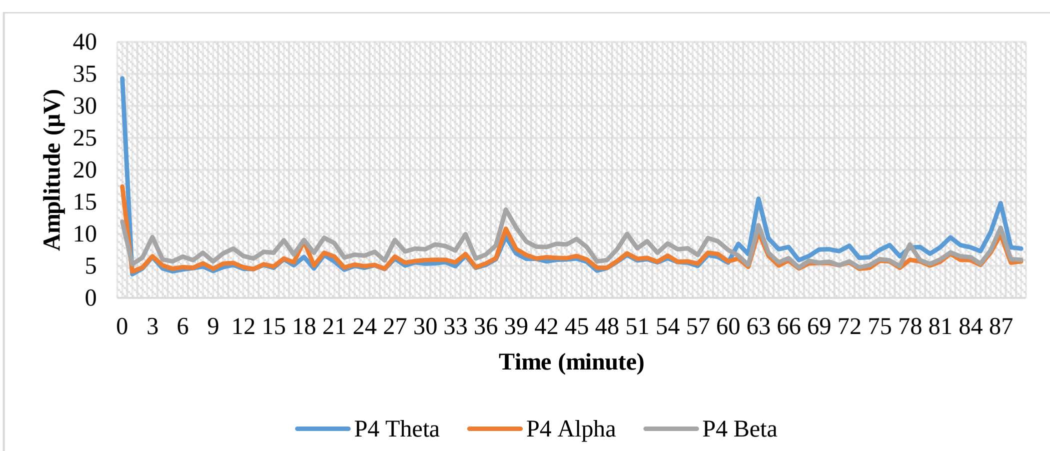


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

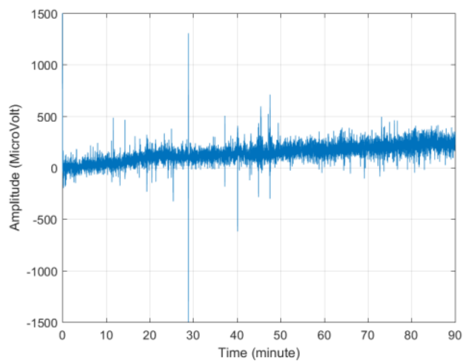


APPENDICES 4

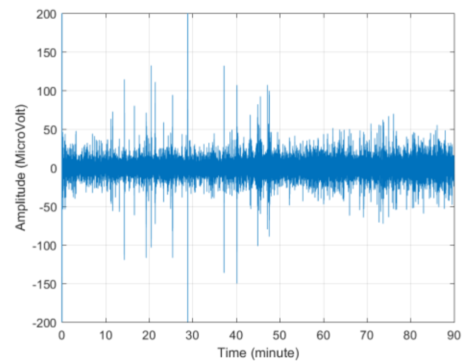
AUTODIDACT IN THE LATE MORNING [PARTICIPANT 4]

1. F3 channel

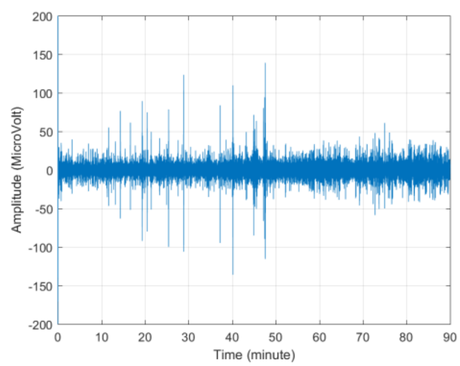
   a. EEG Signal



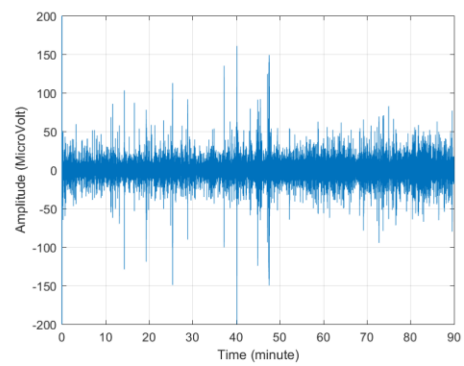
EEG Raw Data



Theta (4-8 Hz)

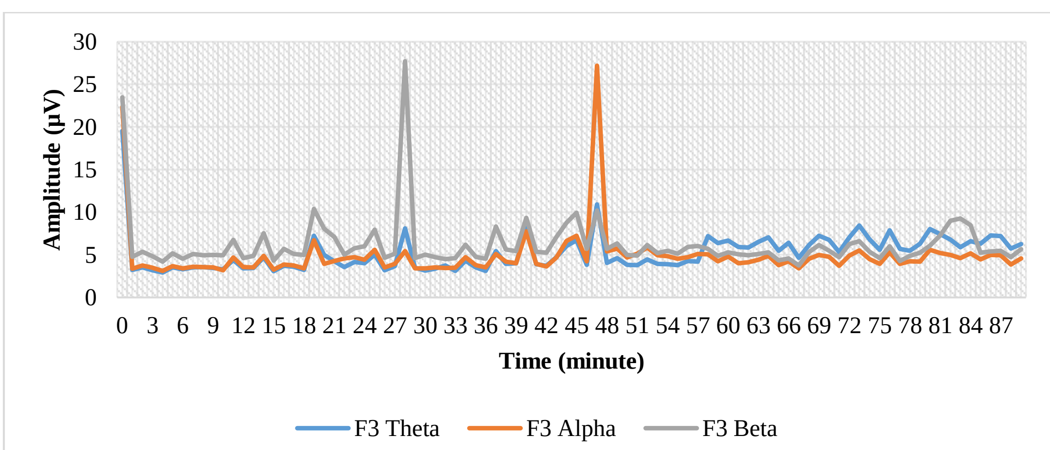


Alpha (8-13 Hz)



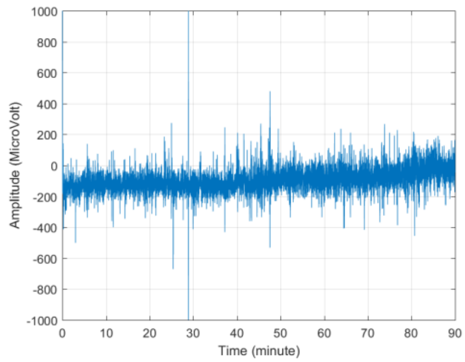
Beta (13-30 Hz)

   b. RMS calculation

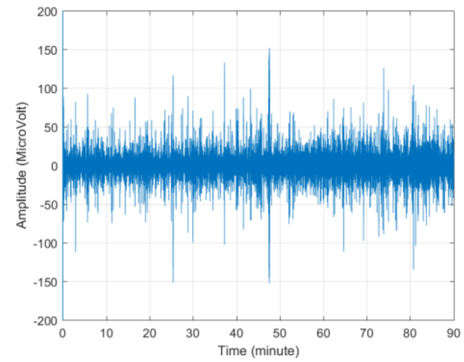


2. F4 channel

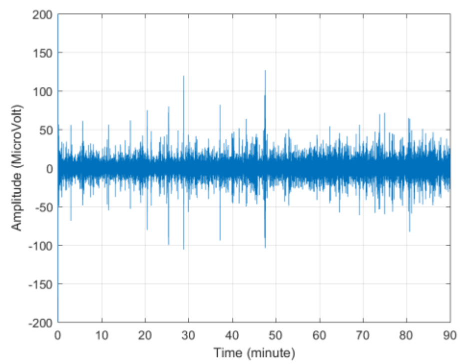
a. EEG Signal



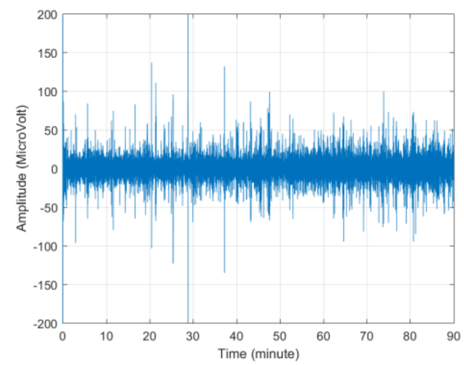
EEG Raw Data



Theta (4-8 Hz)

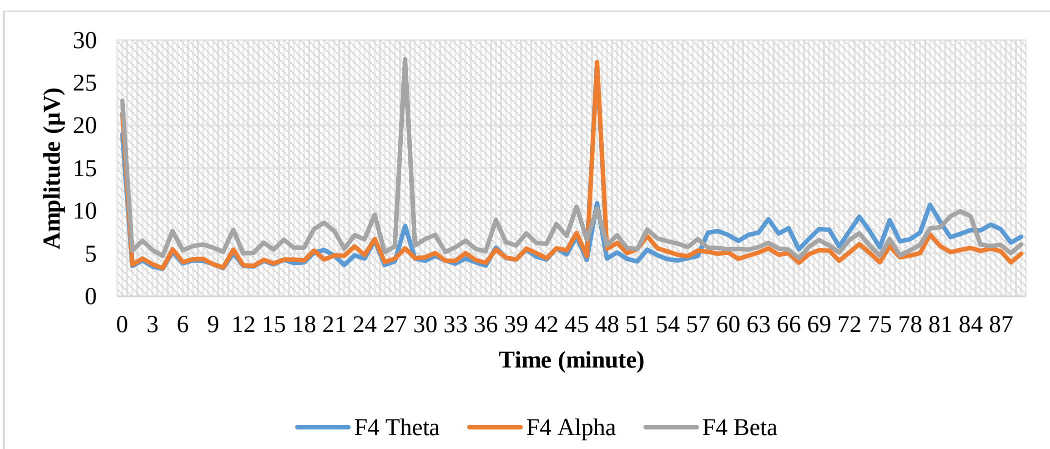


Alpha (8-13 Hz)



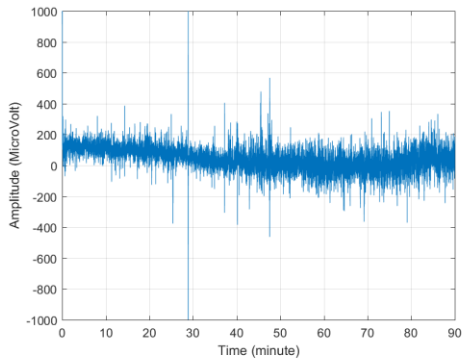
Beta (13-30 Hz)

b. RMS calculation

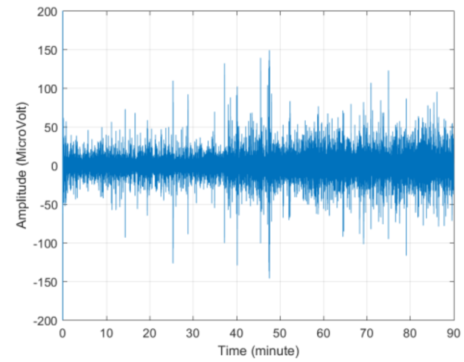


3. P3 channel

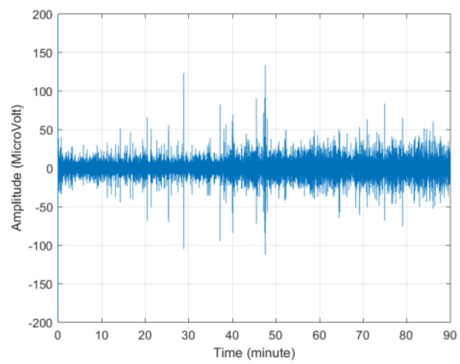
a. EEG Signal



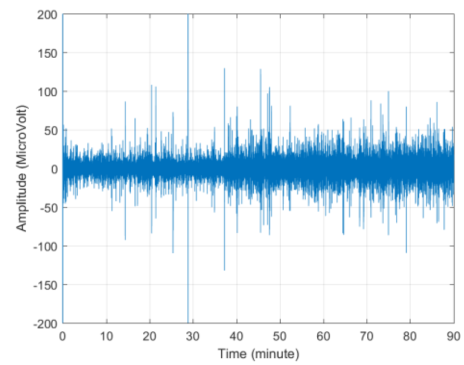
EEG Raw Data



Theta (4-8 Hz)

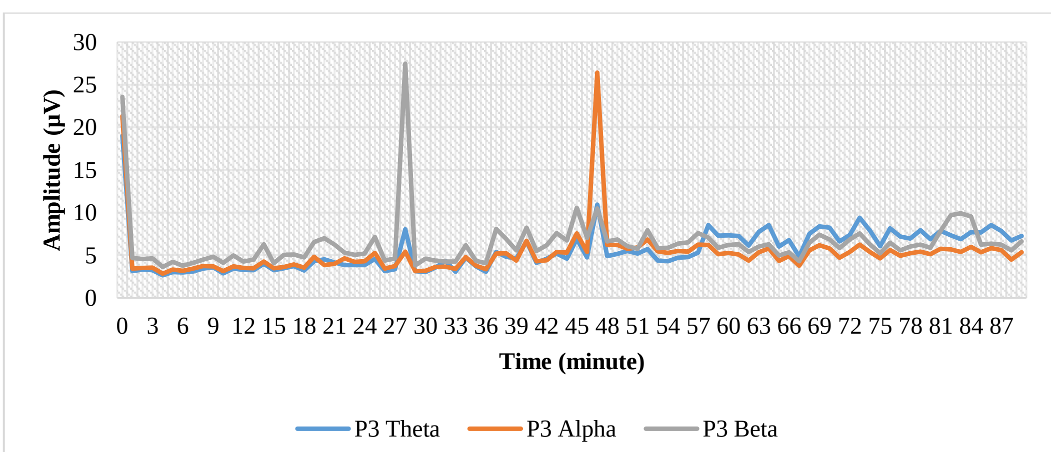


Alpha (8-13 Hz)



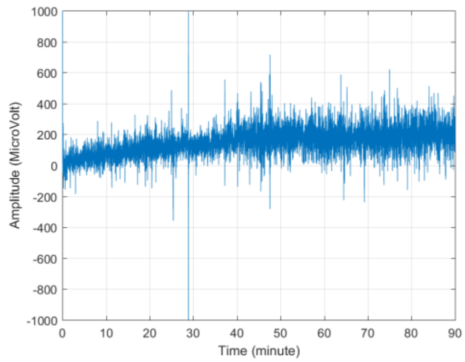
Beta (13-30 Hz)

b. RMS calculation

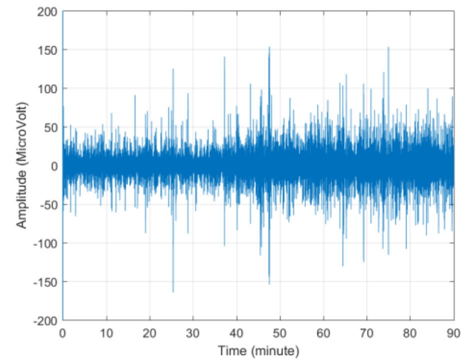


4. P4 channel

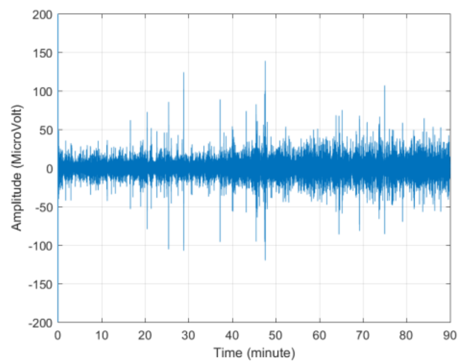
a. EEG Signal



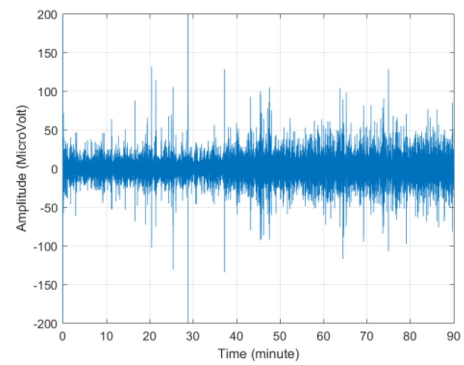
EEG Raw Data



Theta (4-8 Hz)

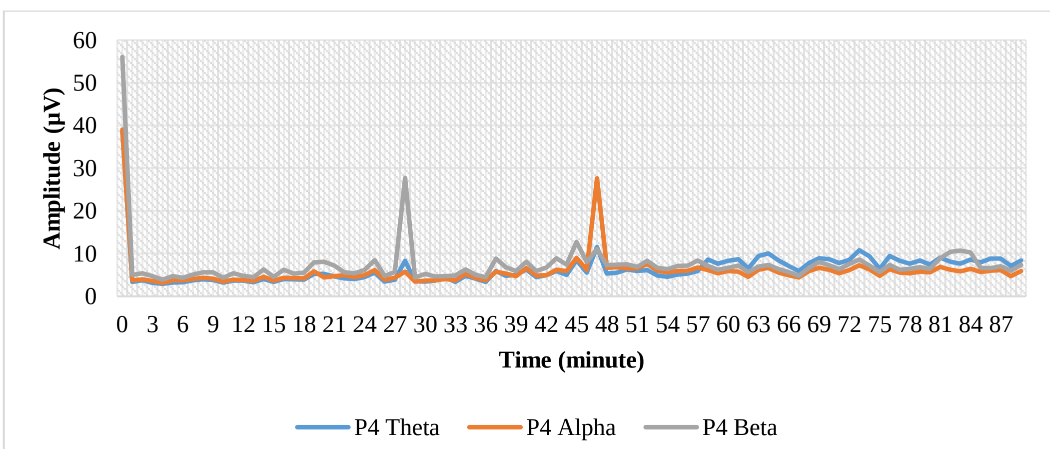


Alpha (8-13 Hz)



Beta (13-30 Hz)

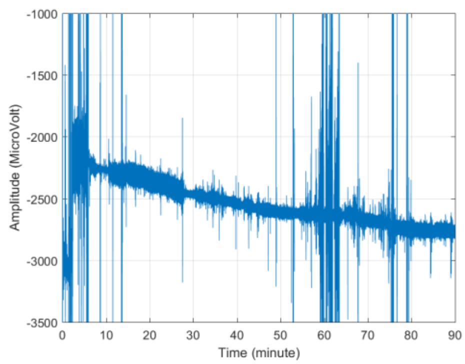
b. RMS calculation



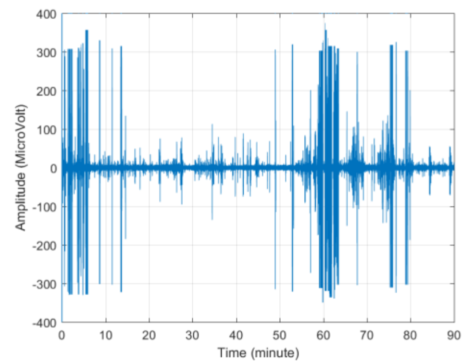
APPENDICES 5

AUTODIDACT IN THE AFTERNOON [PARTICIPANT 1]

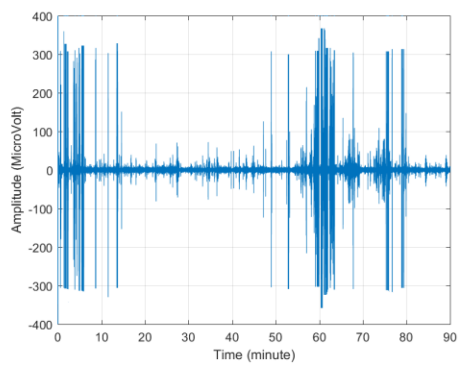
1. F3 channel
   a. EEG Signal



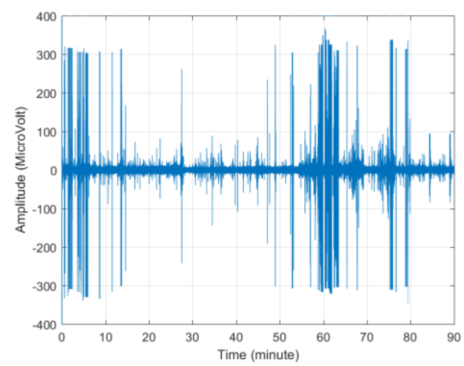
EEG Raw Data



Theta (4-8 Hz)

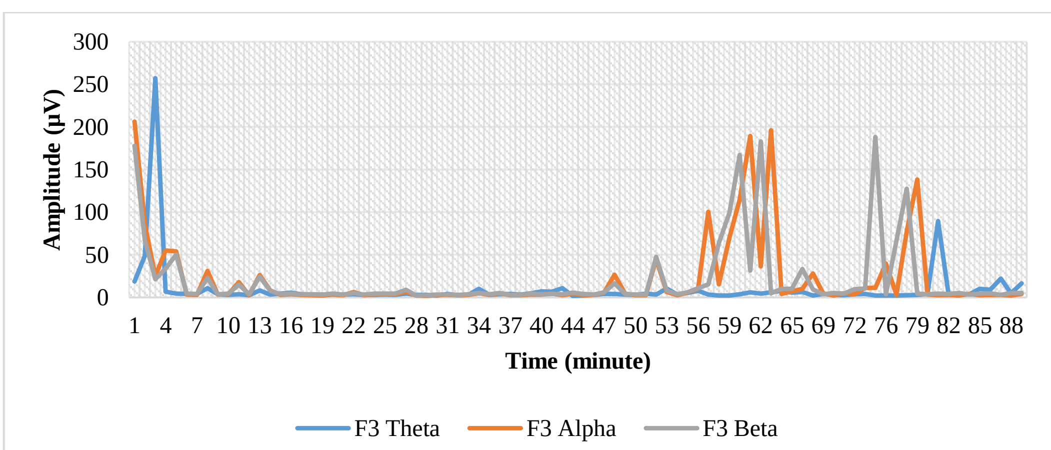


Alpha (8-13 Hz)



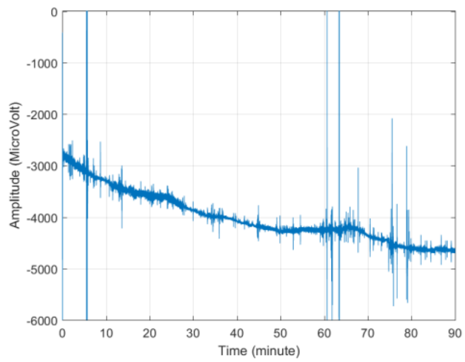
Beta (13-30 Hz)

   b. RMS calculation

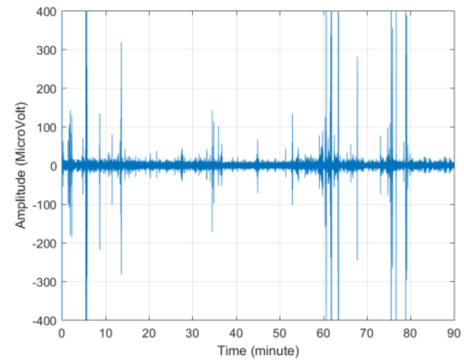


2. F4 channel

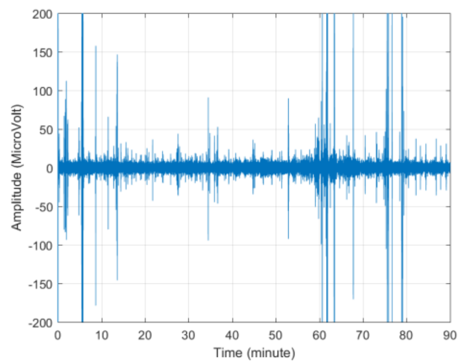
a. EEG Signal



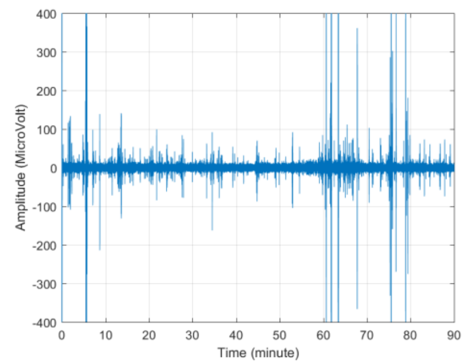
EEG Raw Data



Theta (4-8 Hz)

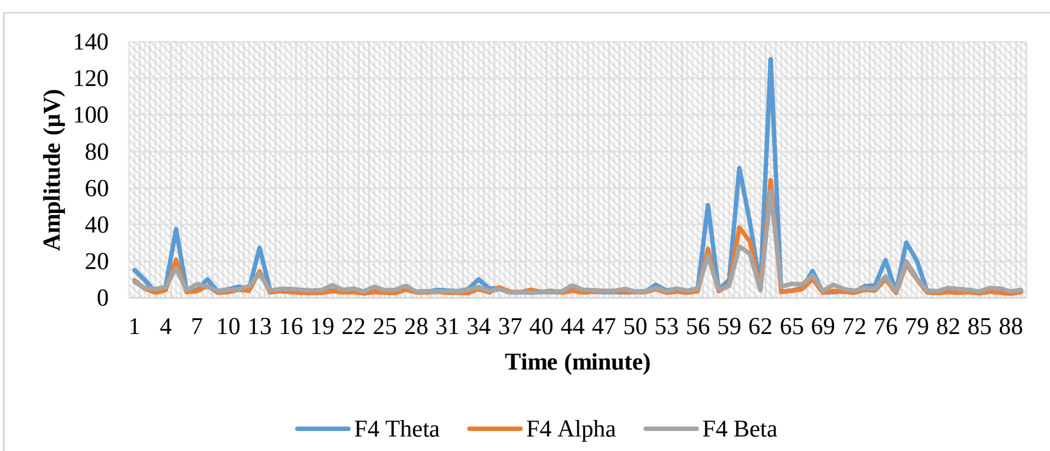


Alpha (8-13 Hz)



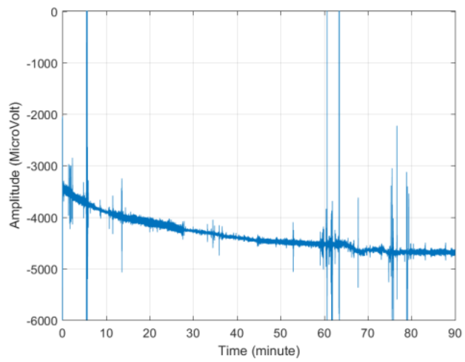
Beta (13-30 Hz)

b. RMS calculation

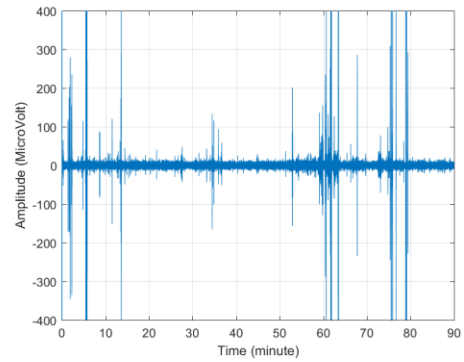


3. P3 channel

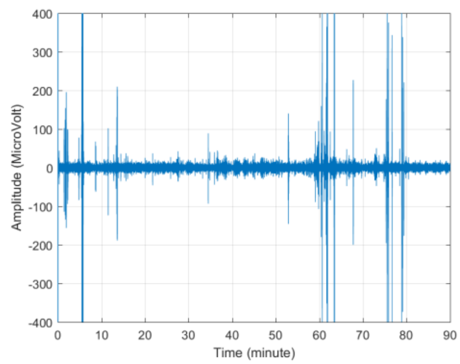
a. EEG Signal



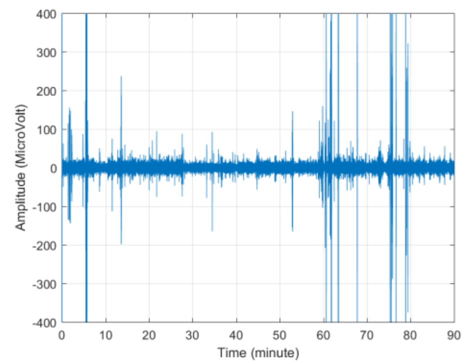
EEG Raw Data



Theta (4-8 Hz)

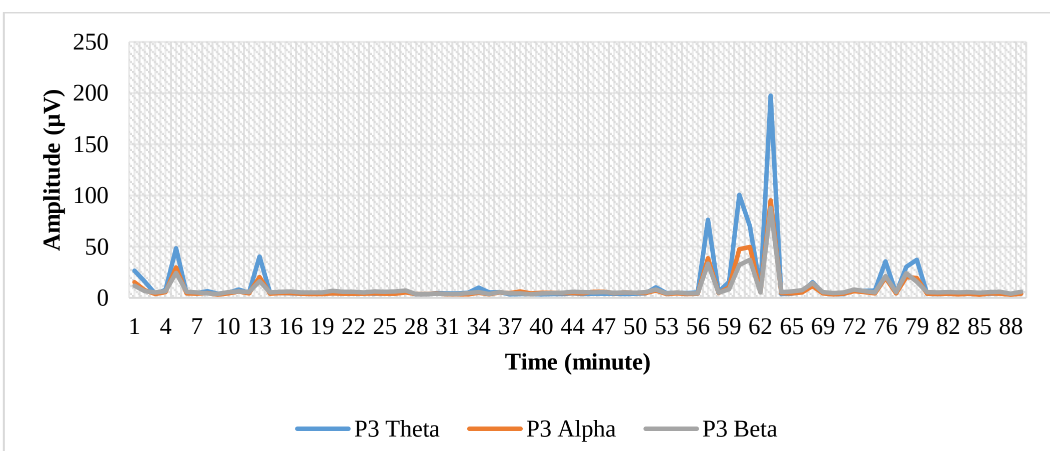


Alpha (8-13 Hz)



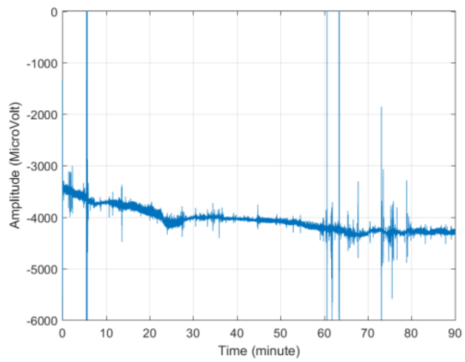
Beta (13-30 Hz)

b. RMS calculation

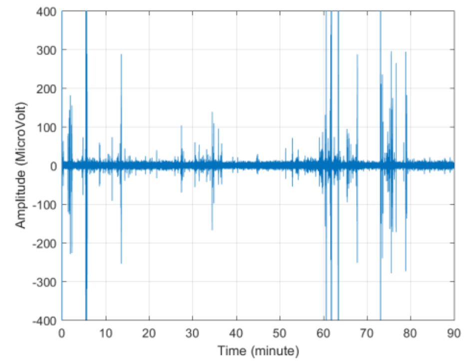


4. P4 channel

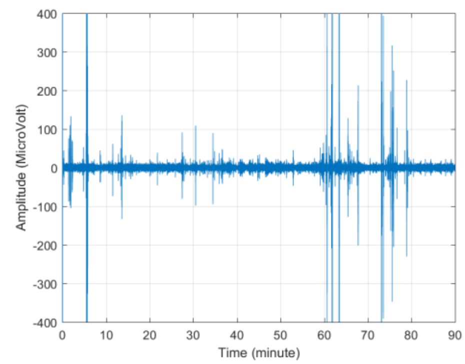
a. EEG Signal



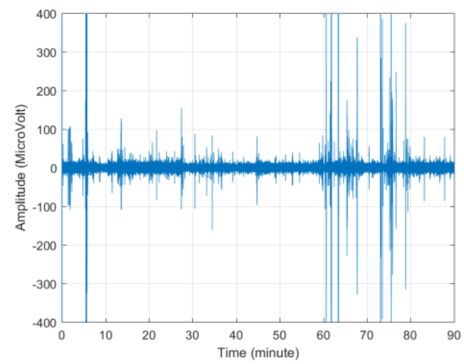
EEG Raw Data



Theta (4-8 Hz)

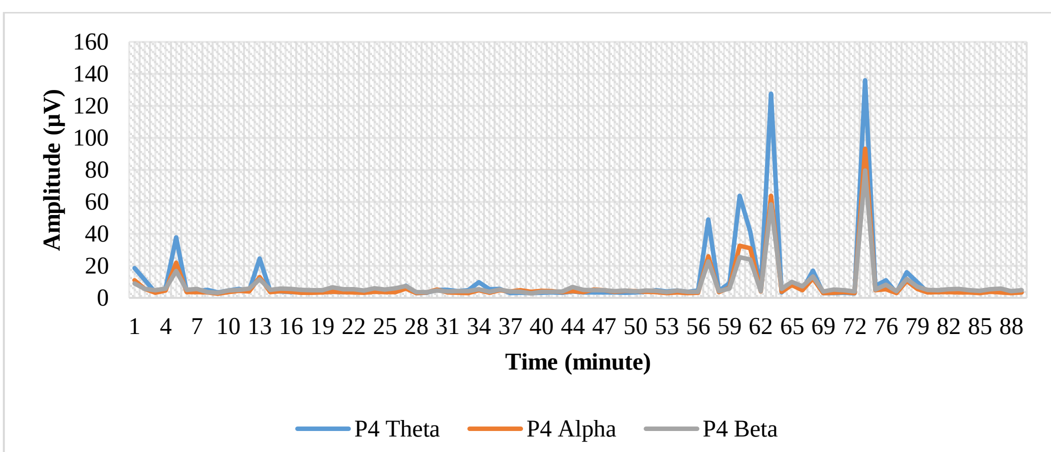


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

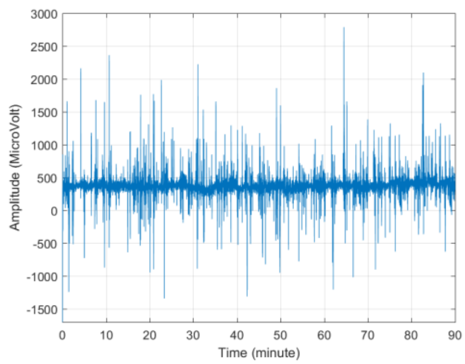


APPENDICES 6

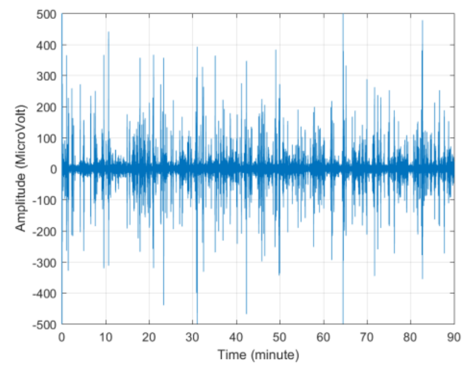
AUTODIDACT IN THE AFTERNOON [PARTICIPANT 2]

1. F3 channel

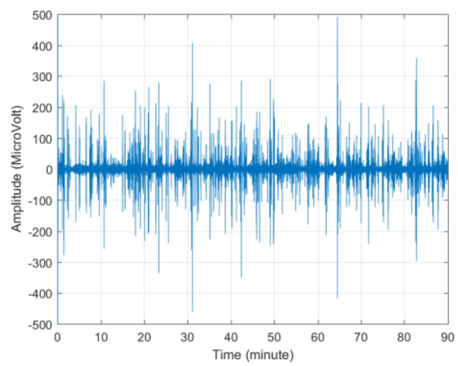
a. EEG Signal



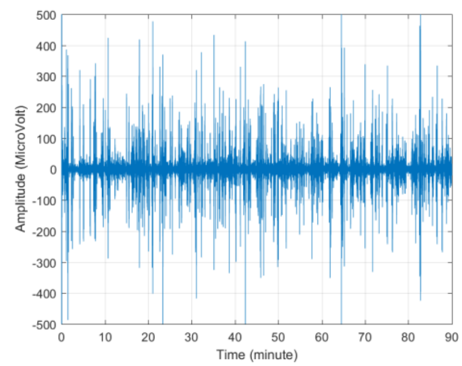
EEG Raw Data



Theta (4-8 Hz)

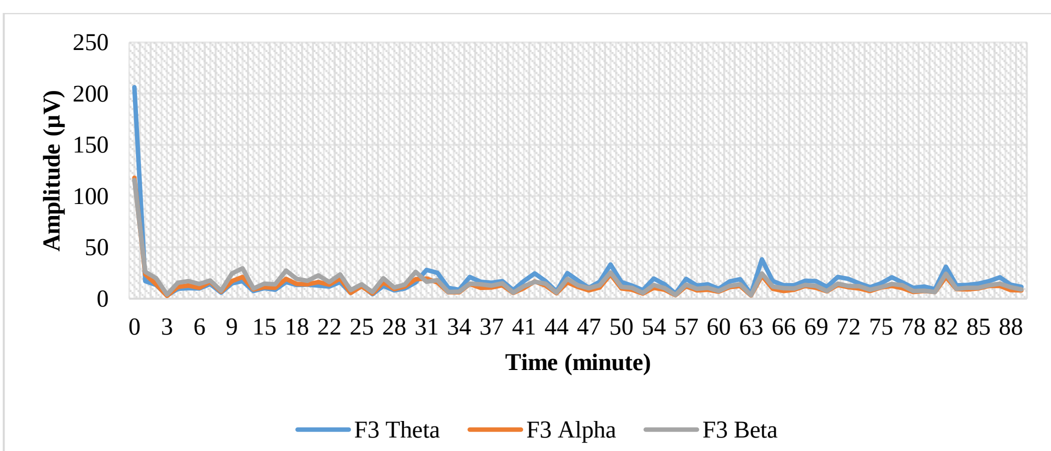


Alpha (8-13 Hz)



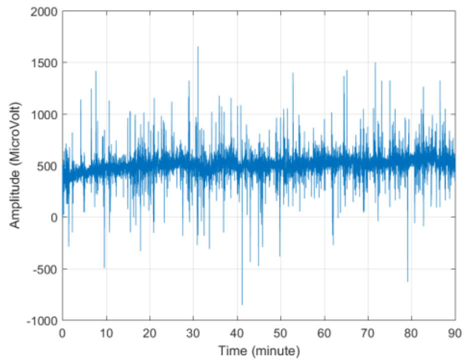
Beta (13-30 Hz)

b. RMS calculation

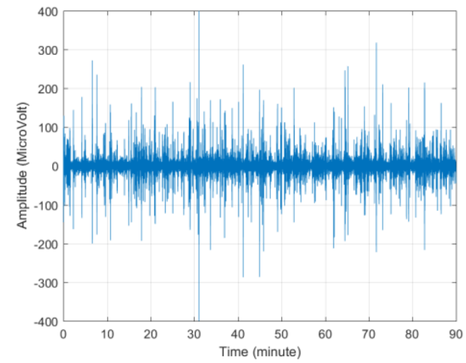


2. F4 channel

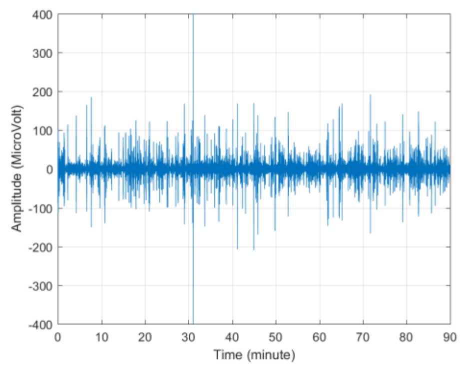
a. EEG Signal



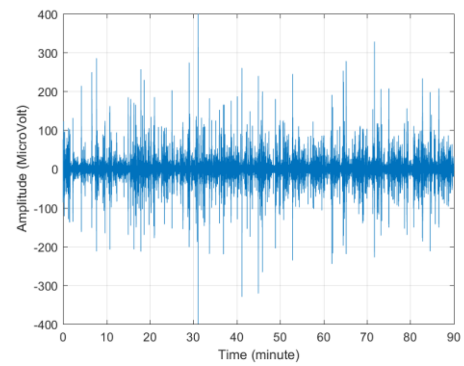
EEG Raw Data



Theta (4-8 Hz)

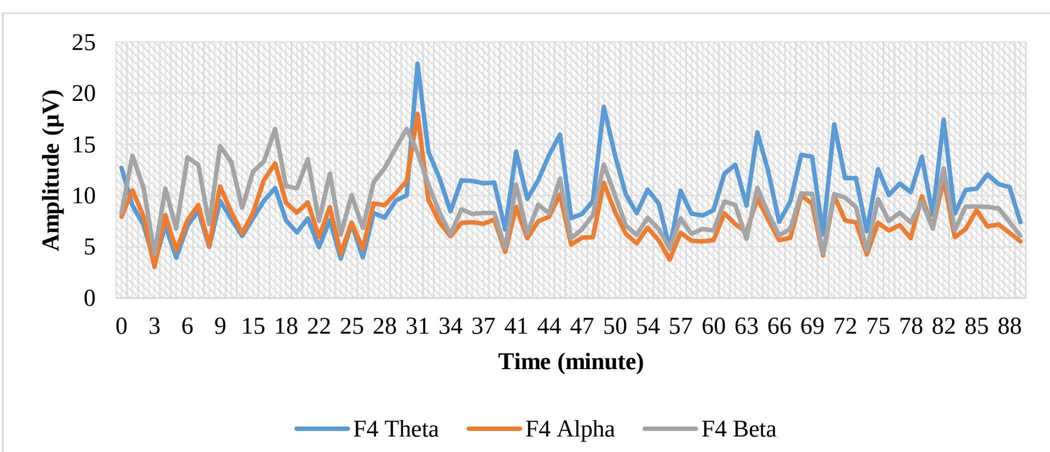


Alpha (8-13 Hz)



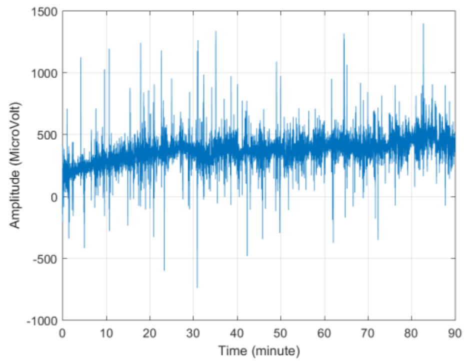
Beta (13-30 Hz)

b. RMS calculation

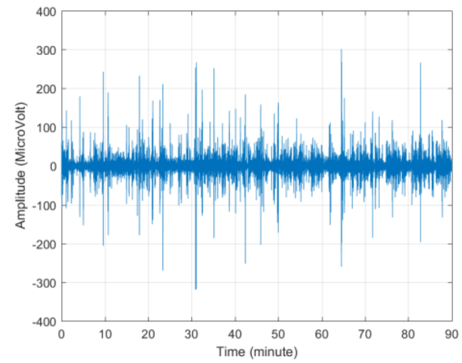


3. P3 channel

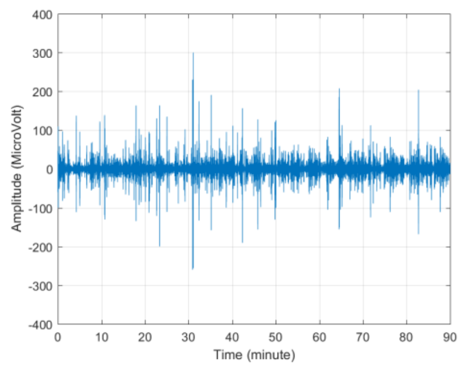
a. EEG Signal



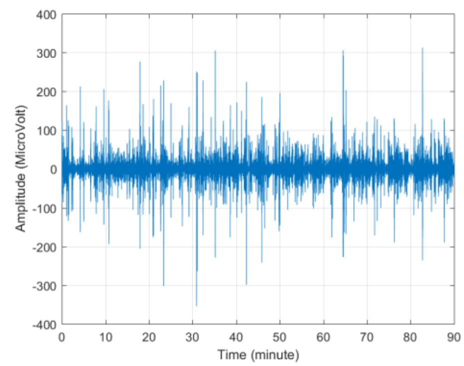
EEG Raw Data



Theta (4-8 Hz)

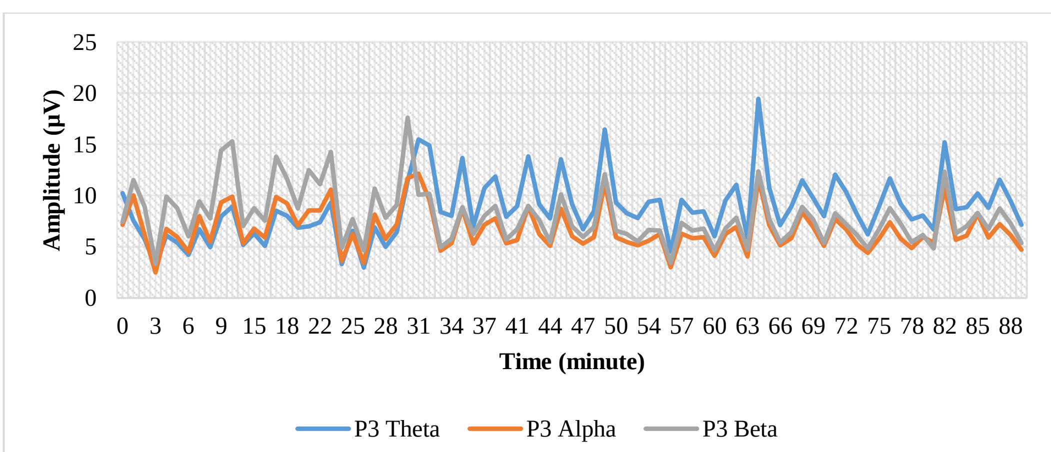


Alpha (8-13 Hz)



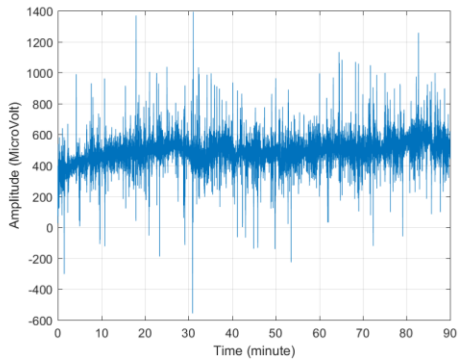
Beta (13-30 Hz)

b. RMS calculation

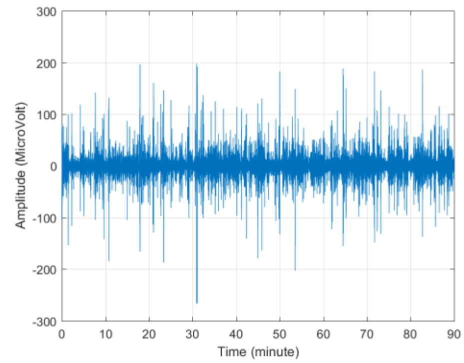


4. P4 channel

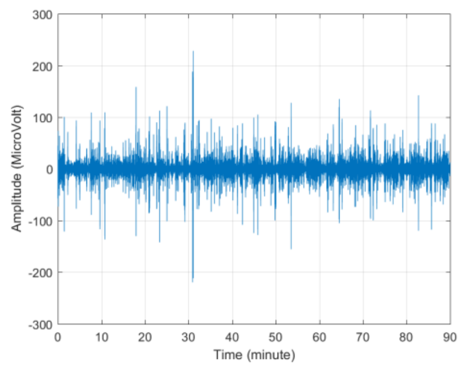
a. EEG Signal



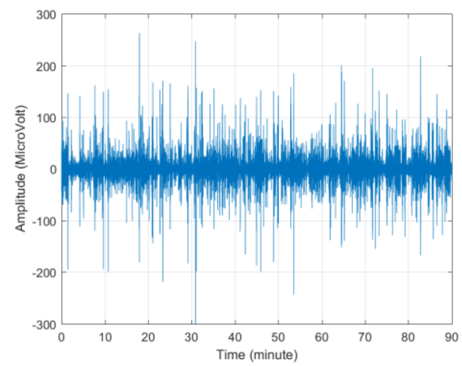
EEG Raw Data



Theta (4-8 Hz)

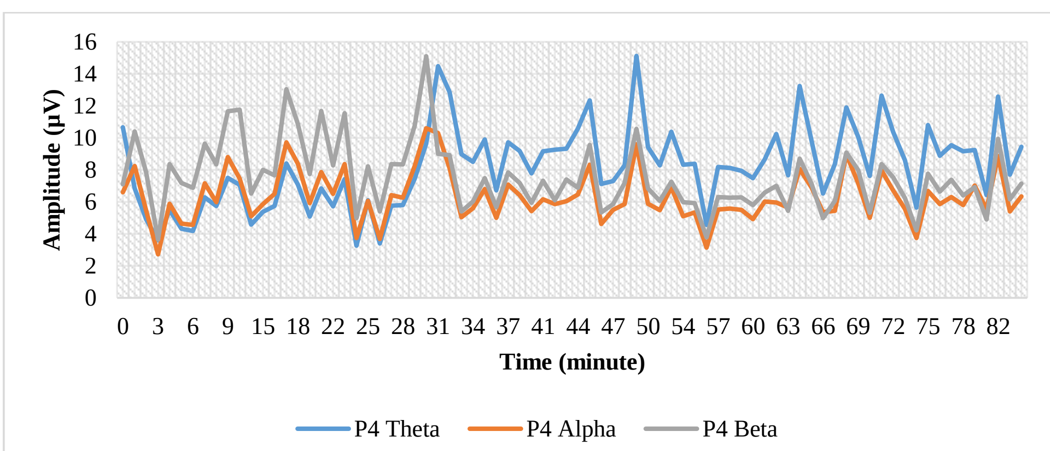


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

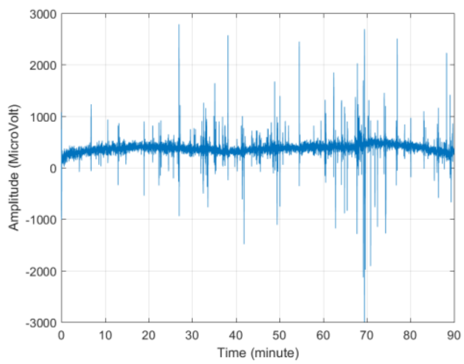


APPENDICES 7

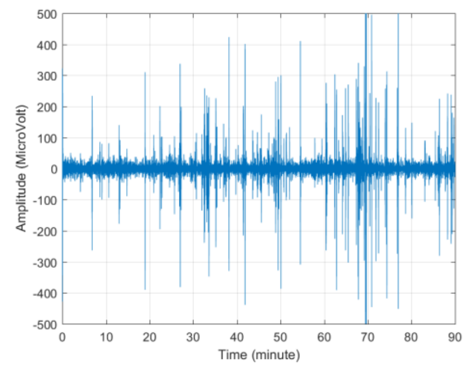
AUTODIDACT IN THE AFTERNOON [PARTICIPANT 3]

1. F3 channel

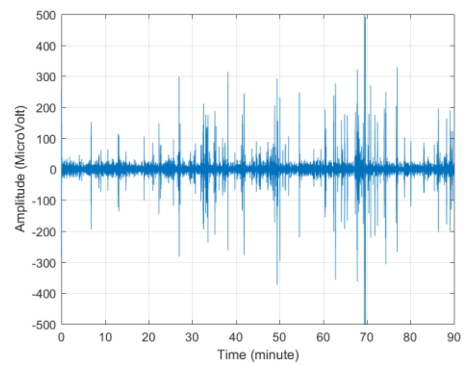
   a. EEG Signal



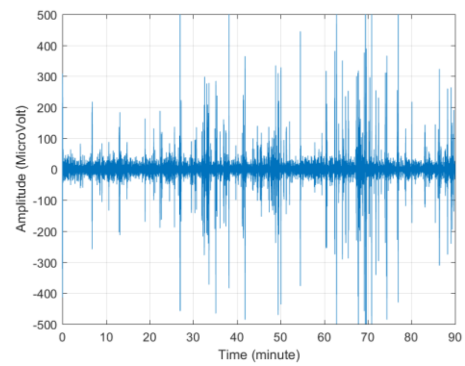
EEG Raw Data



Theta (4-8 Hz)

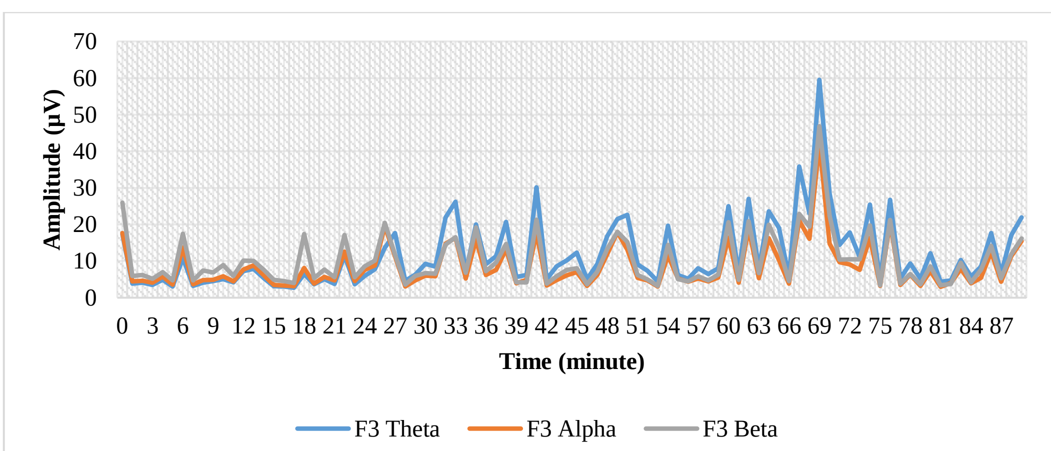


Alpha (8-13 Hz)



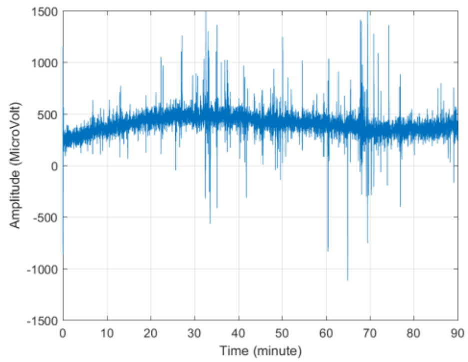
Beta (13-30 Hz)

   b. RMS calculation

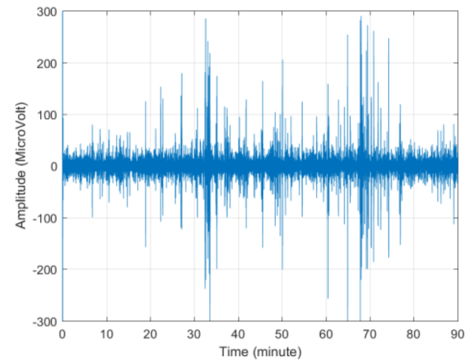


2. F4 channel

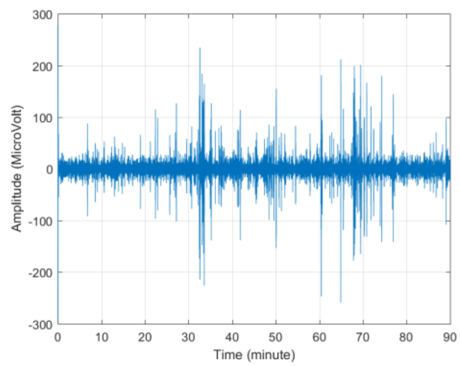
a. EEG Signal



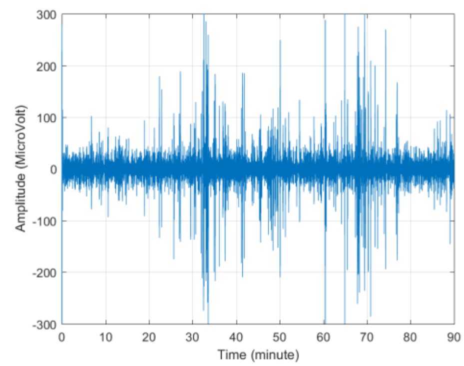
EEG Raw Data



Theta (4-8 Hz)

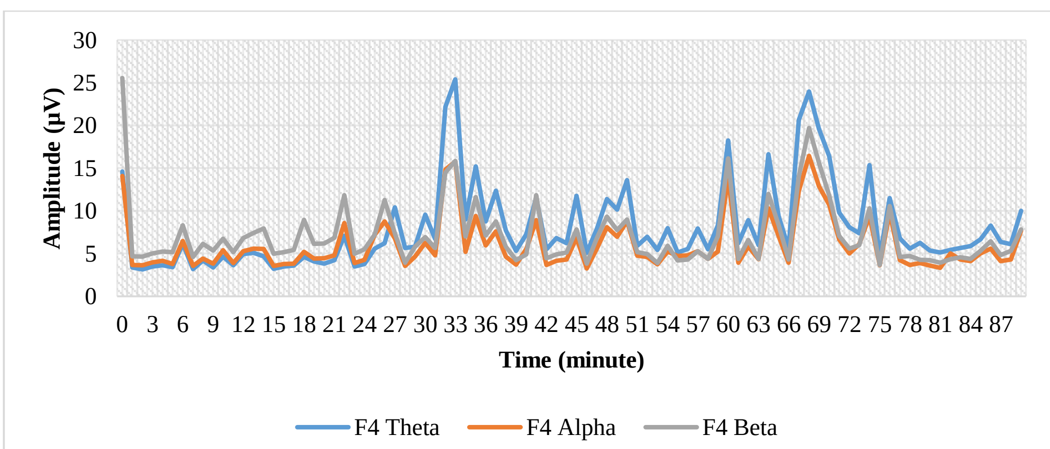


Alpha (8-13 Hz)



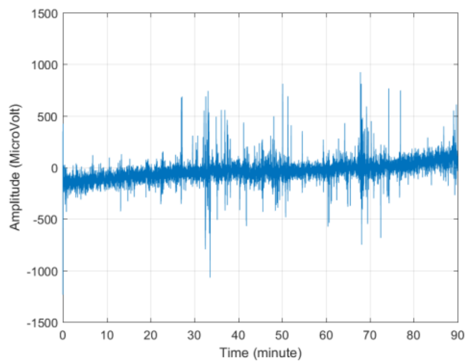
Beta (13-30 Hz)

b. RMS calculation

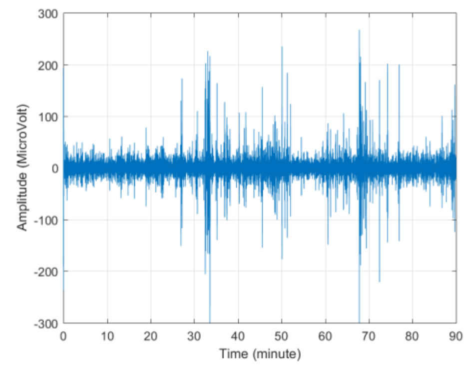


3. P3 channel

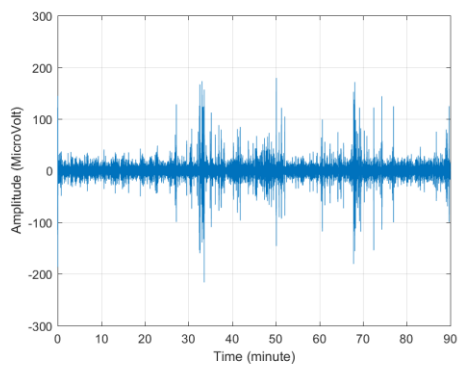
a. EEG Signal



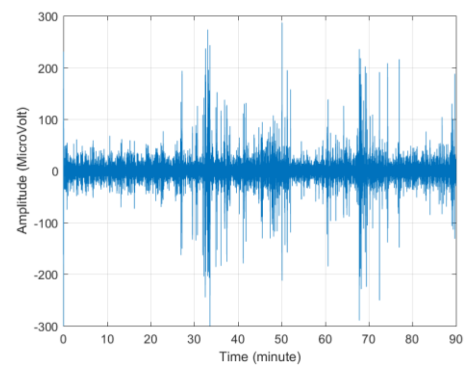
EEG Raw Data



Theta (4-8 Hz)

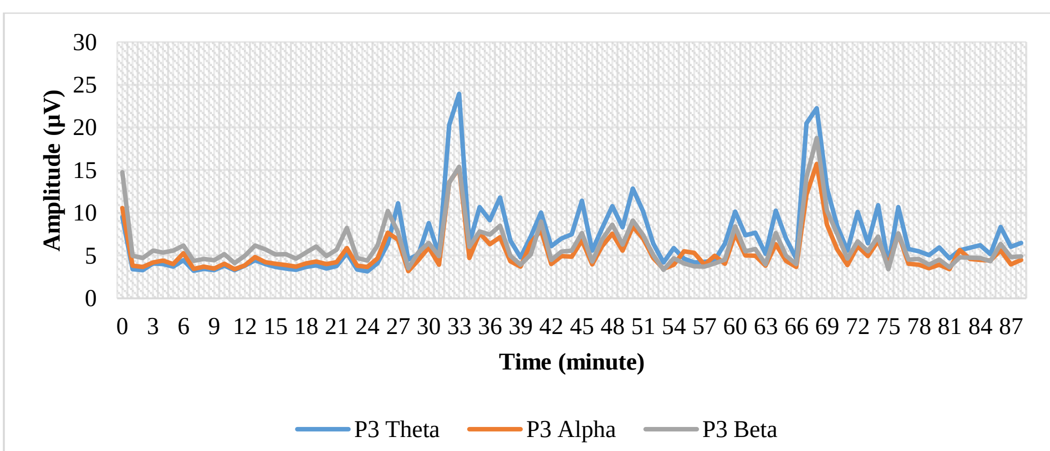


Alpha (8-13 Hz)



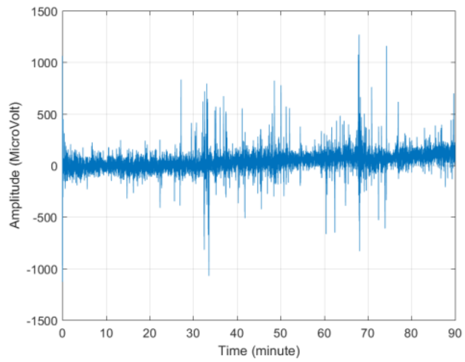
Beta (13-30 Hz)

b. RMS calculation

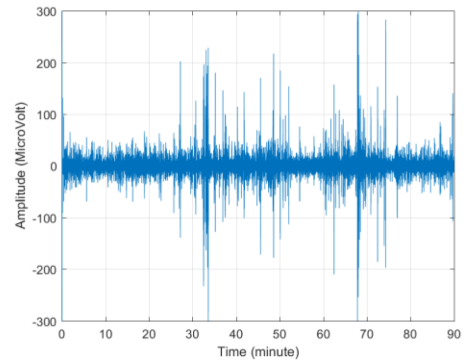


4. P4 channel

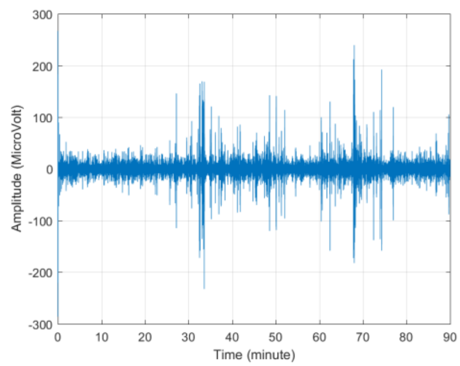
a. EEG Signal



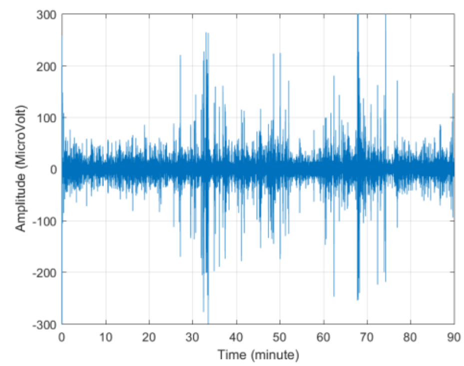
EEG Raw Data



Theta (4-8 Hz)

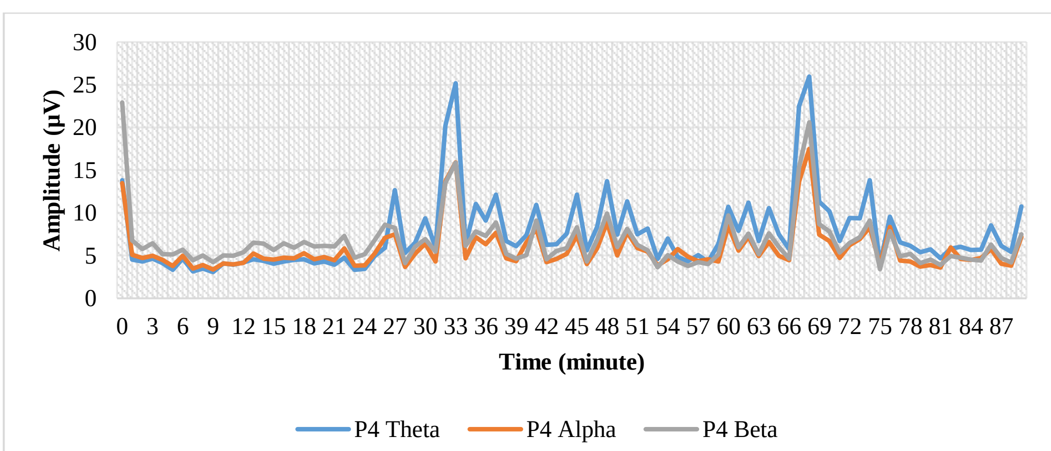


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

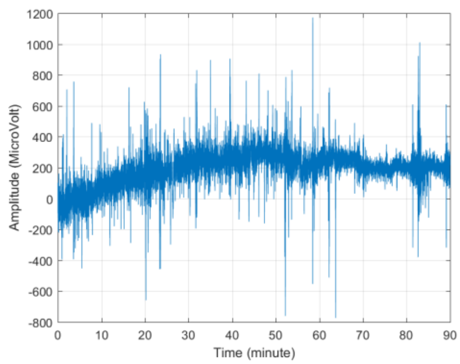


APPENDICES 8

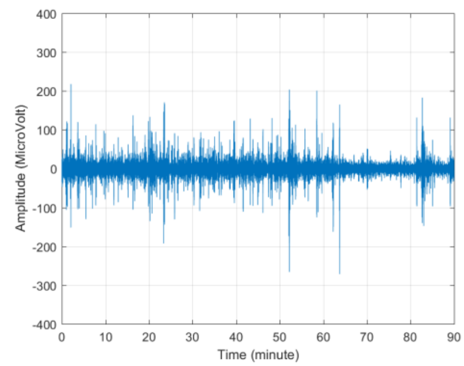
AUTODIDACT IN THE AFTERNOON [PARTICIPANT 4]

1. F3 channel

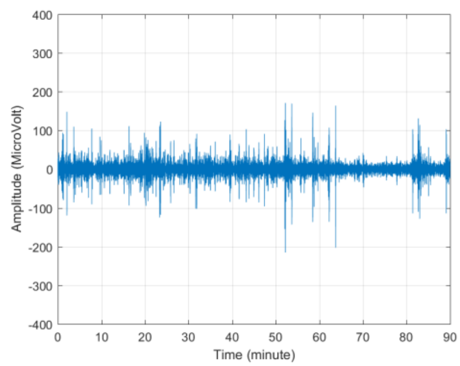
a. EEG Signal



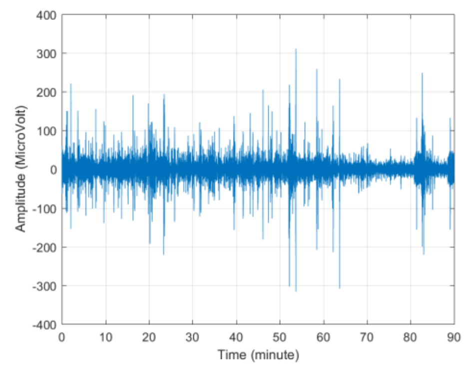
EEG Raw Data



Theta (4-8 Hz)

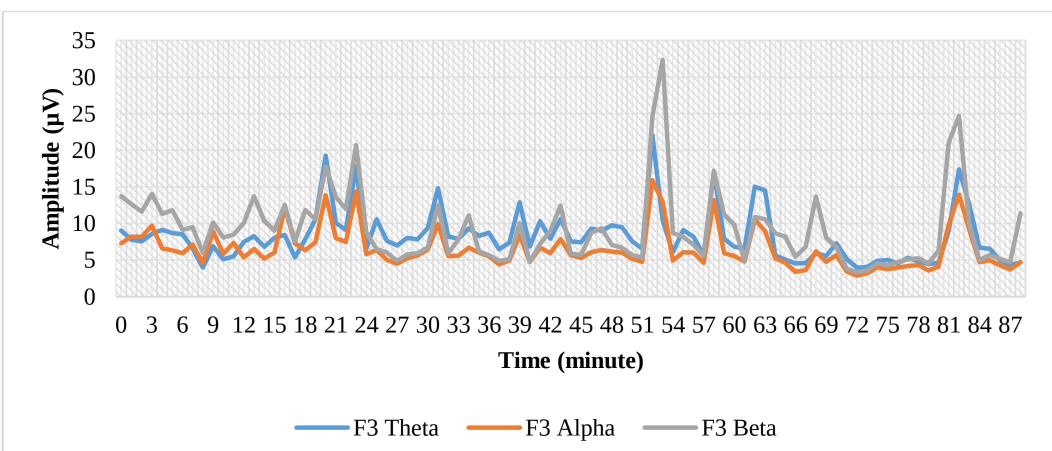


Alpha (8-13 Hz)



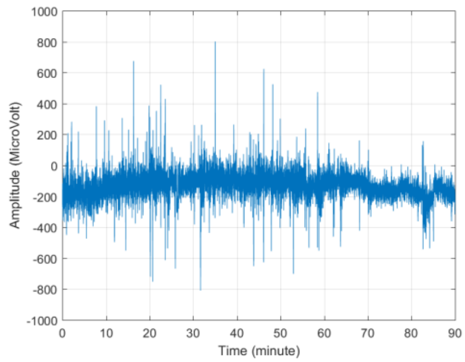
Beta (13-30 Hz)

b. RMS calculation

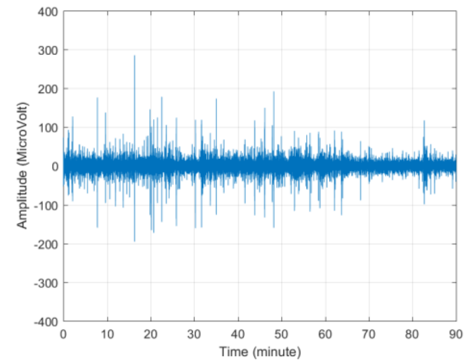


2. F4 channel

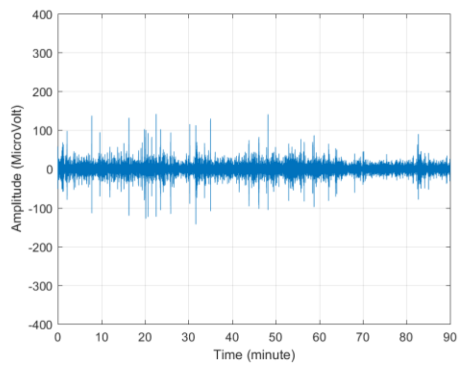
a. EEG Signal



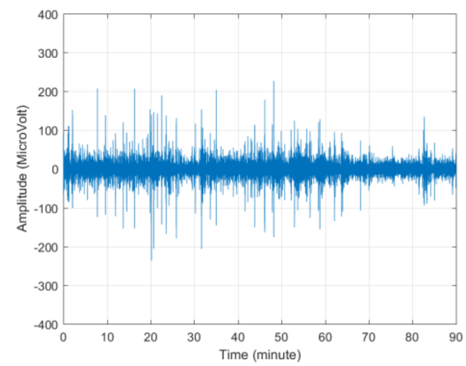
EEG Raw Data



Theta (4-8 Hz)

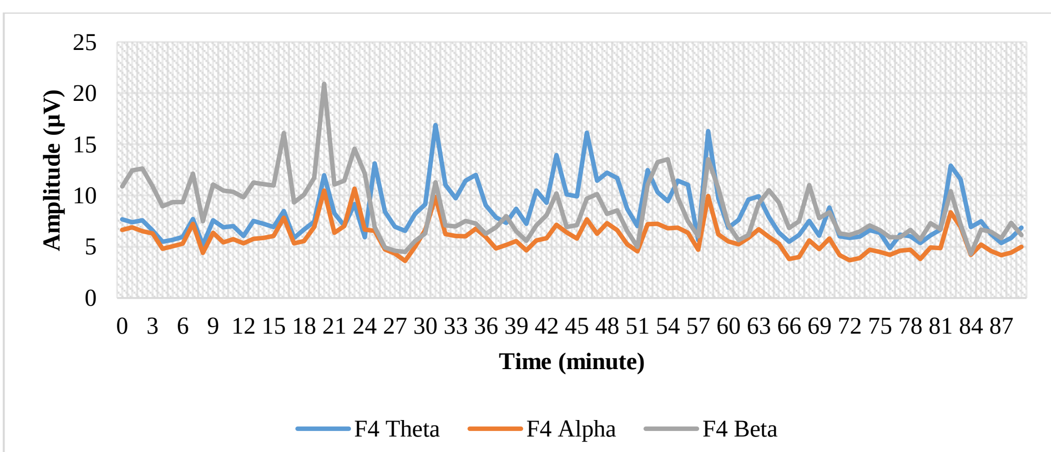


Alpha (8-13 Hz)



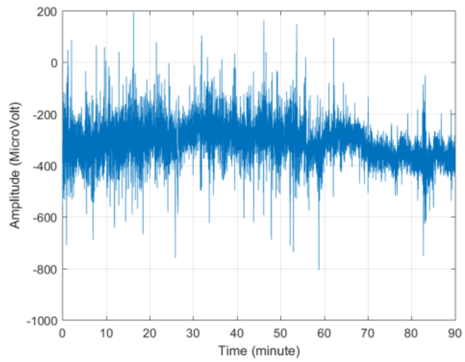
Beta (13-30 Hz)

b. RMS calculation

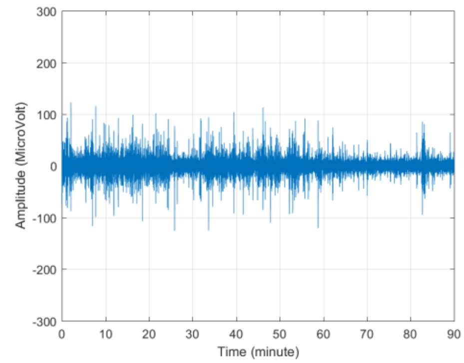


3. P3 channel

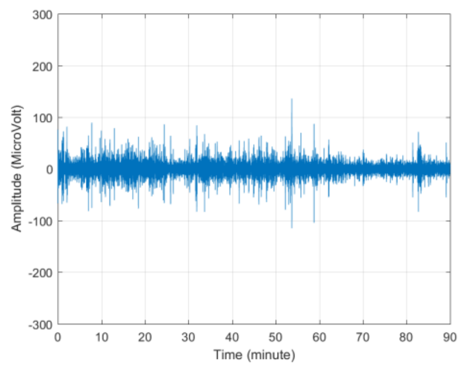
a. EEG Signal



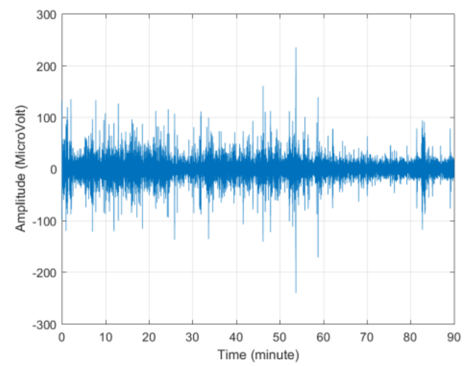
EEG Raw Data



Theta (4-8 Hz)

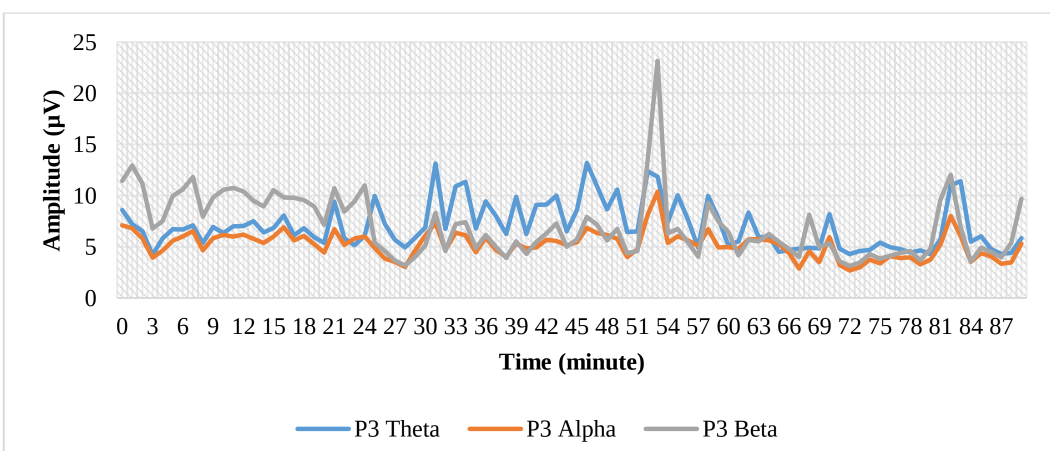


Alpha (8-13 Hz)



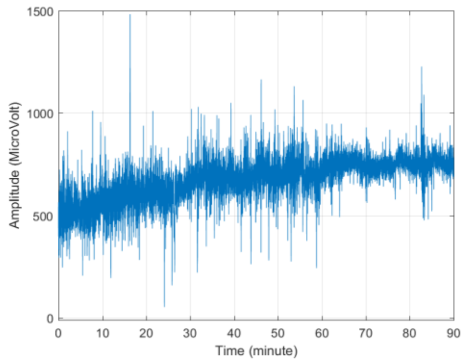
Beta (13-30 Hz)

b. RMS calculation

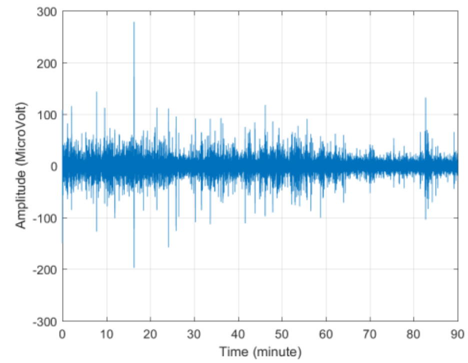


4. P4 channel

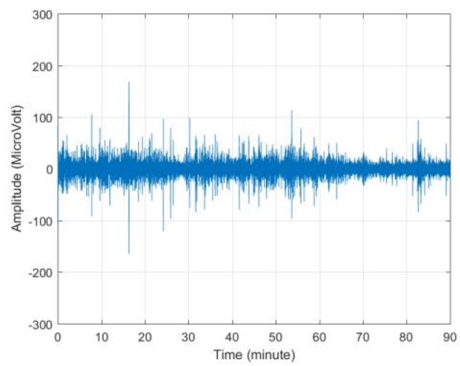
a. EEG Signal



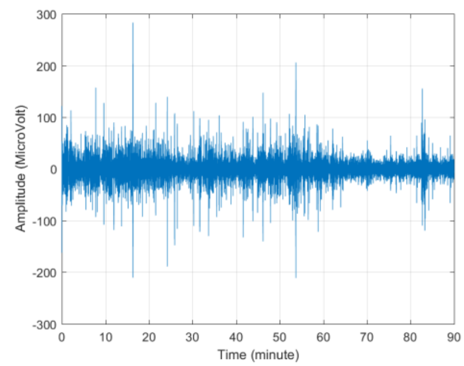
EEG Raw Data



Theta (4-8 Hz)

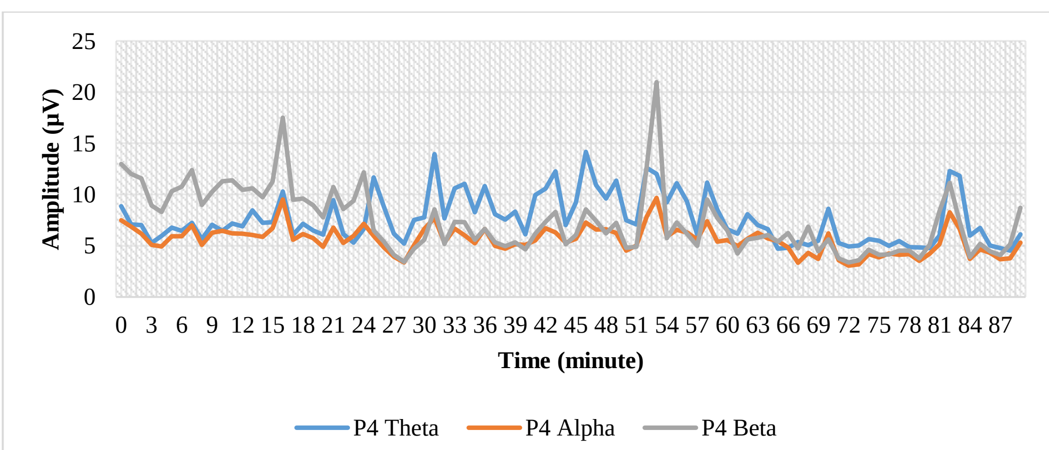


Alpha (8-13 Hz)



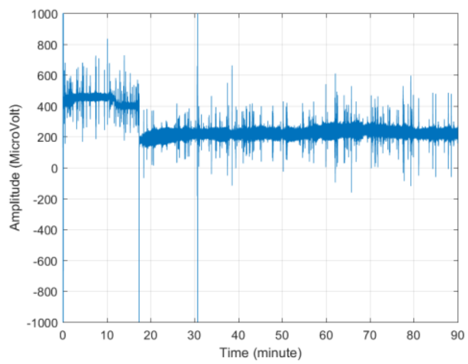
Beta (13-30 Hz)

b. RMS calculation

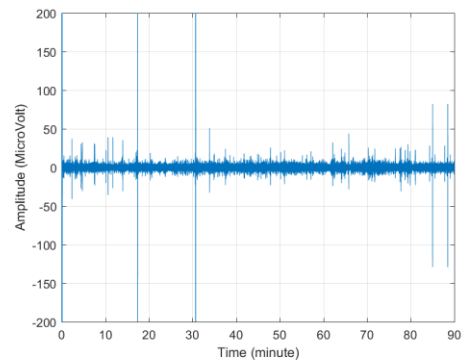


APPENDICES 9
NON-AUTODIDACT IN THE LATE MORNING [PARTICIPANT 1]

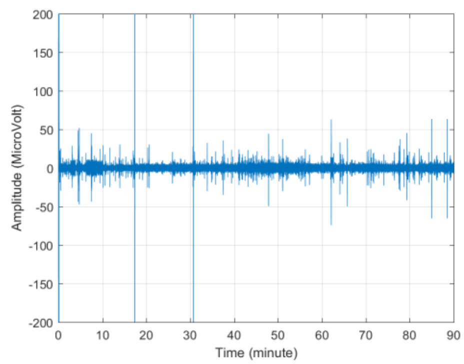
1. F3 channel
   a. EEG Signal



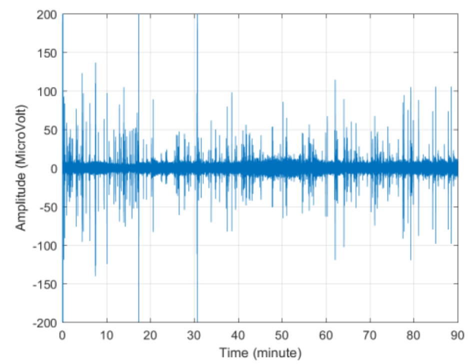
EEG Raw Data



Theta (4-8 Hz)

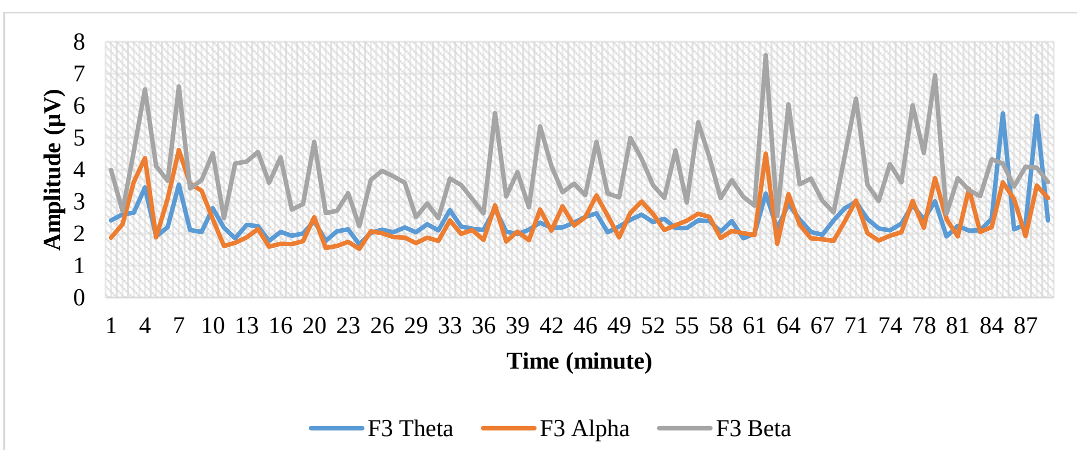


Alpha (8-13 Hz)



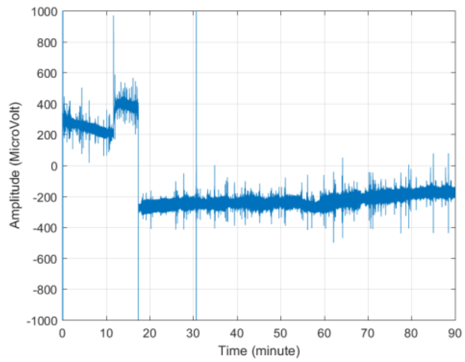
Beta (13-30 Hz)

   b. RMS calculation

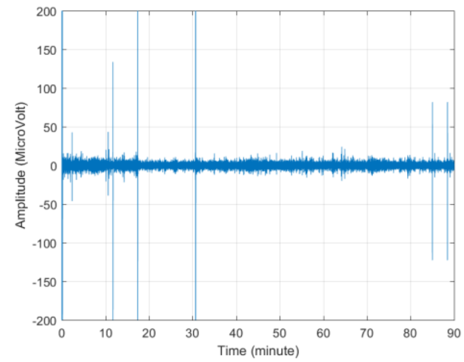


2. F4 channel

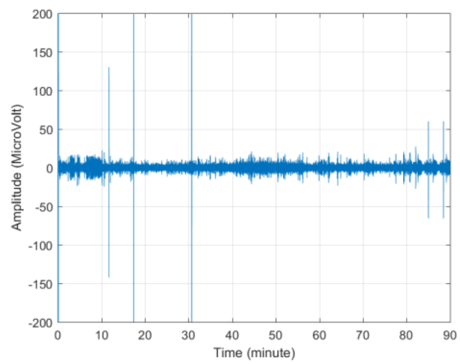
a. EEG Signal



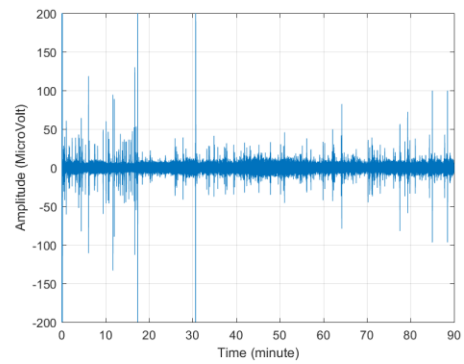
EEG Raw Data



Theta (4-8 Hz)

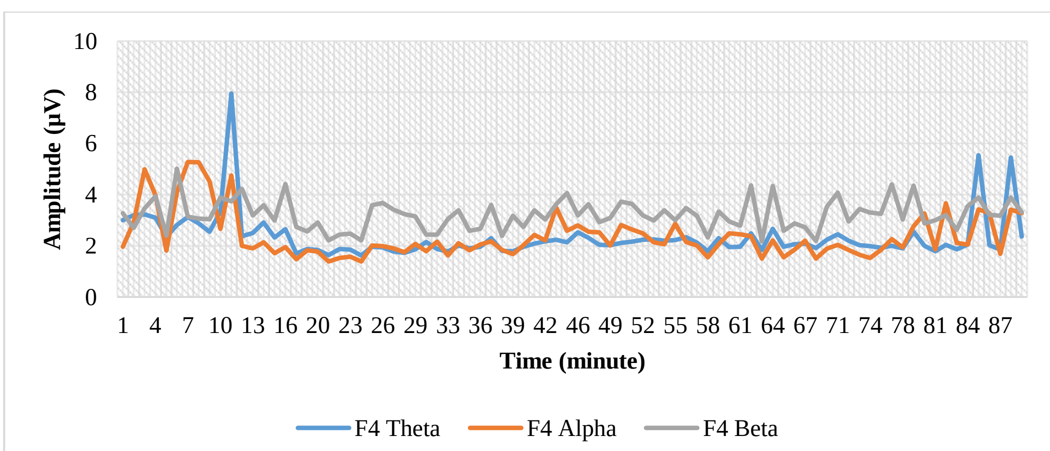


Alpha (8-13 Hz)



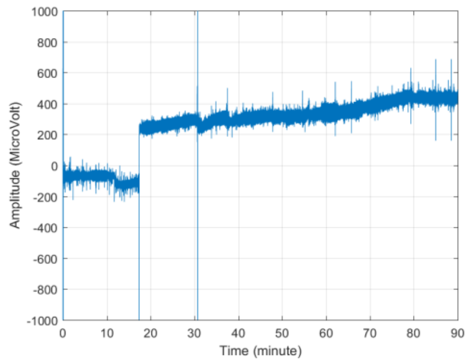
Beta (13-30 Hz)

b. RMS calculation

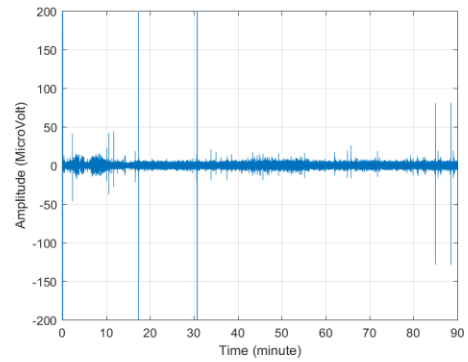


3. P3 channel

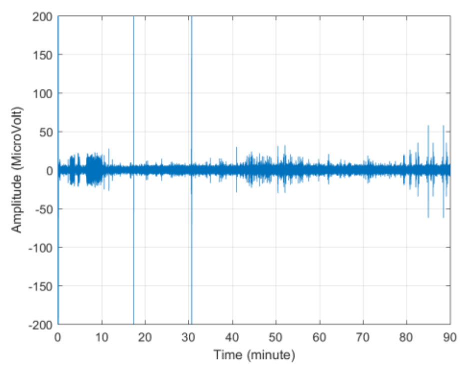
a. EEG Signal



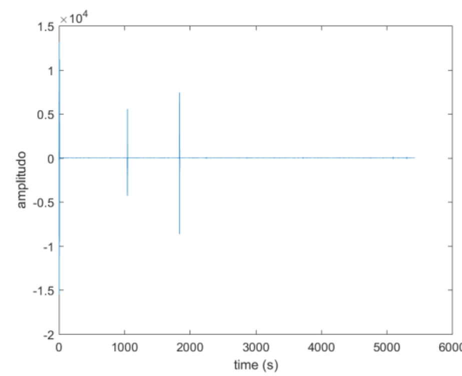
EEG Raw Data



Theta (4-8 Hz)

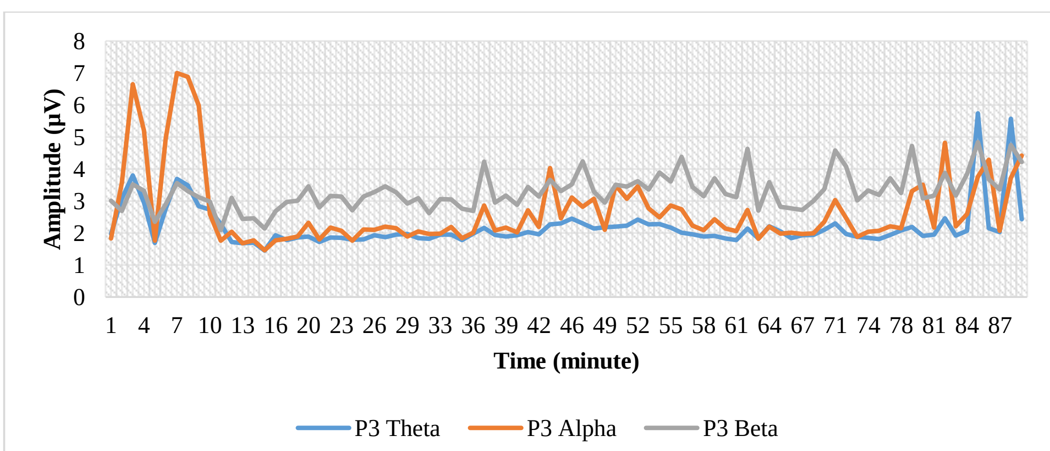


Alpha (8-13 Hz)



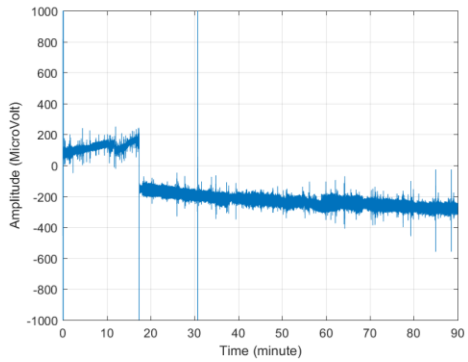
Beta (13-30 Hz)

b. RMS calculation

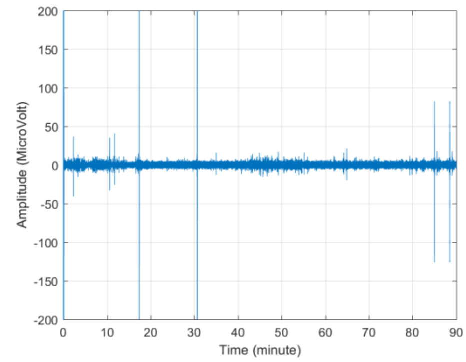


4. P4 channel

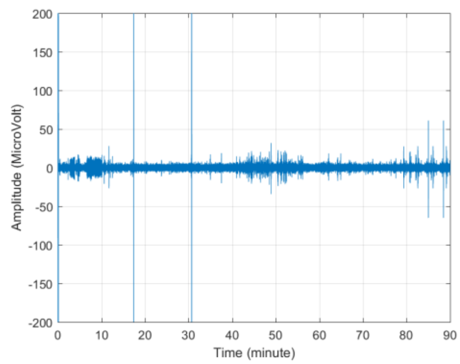
a. EEG Signal



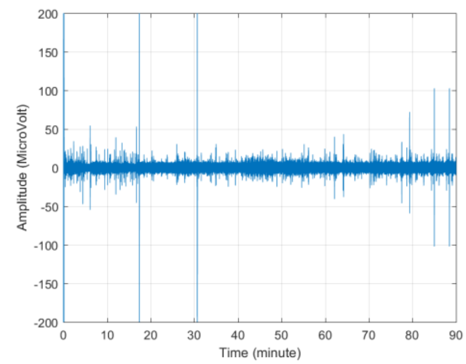
EEG Raw Data



Theta (4-8 Hz)

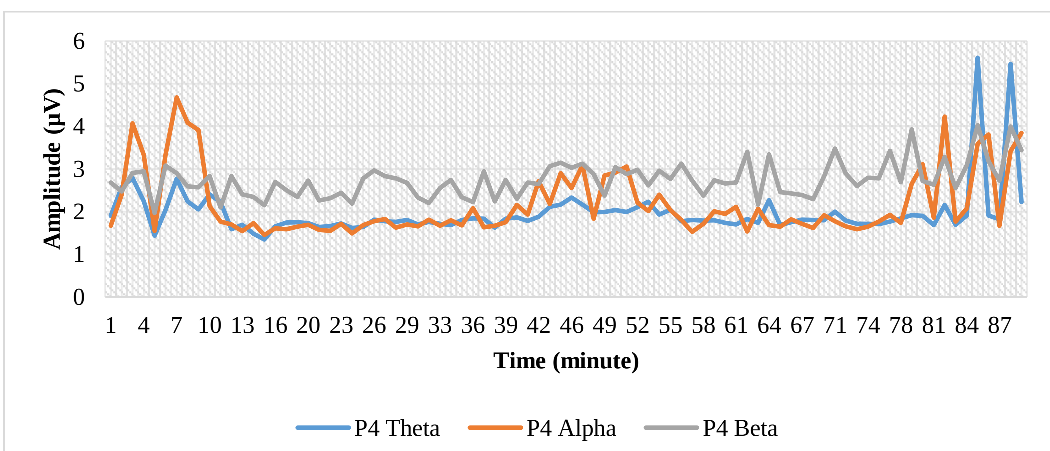


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

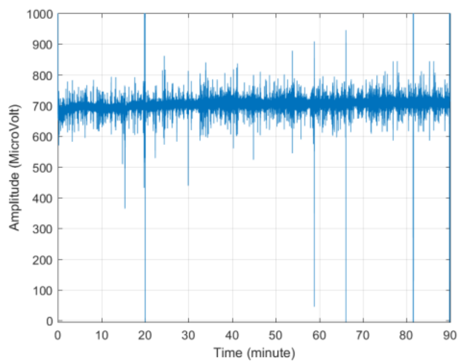


APPENDICES 10

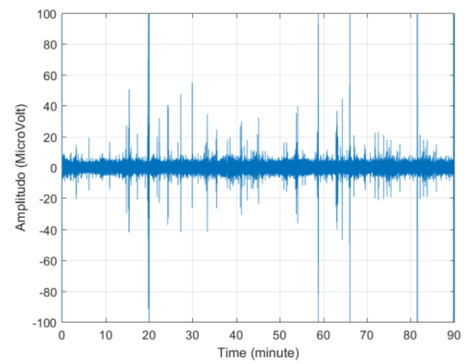
NON-AUTODIDACT IN THE LATE MORNING [PARTICIPANT 2]

1. F3 channel

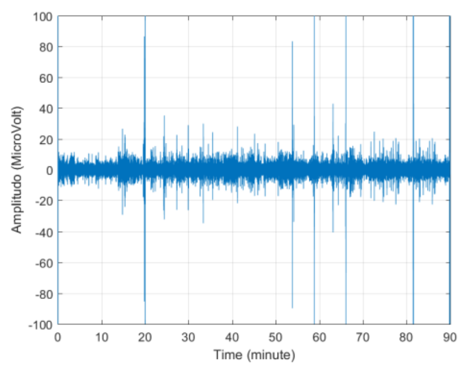
   a. EEG Signal



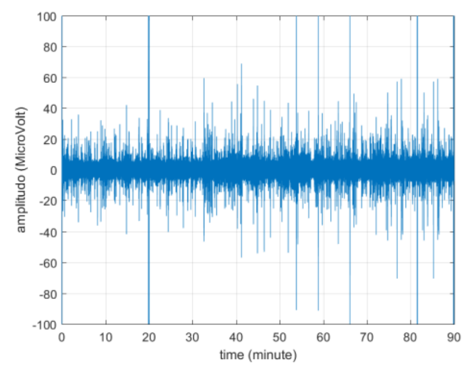
EEG Raw Data



Theta (4-8 Hz)

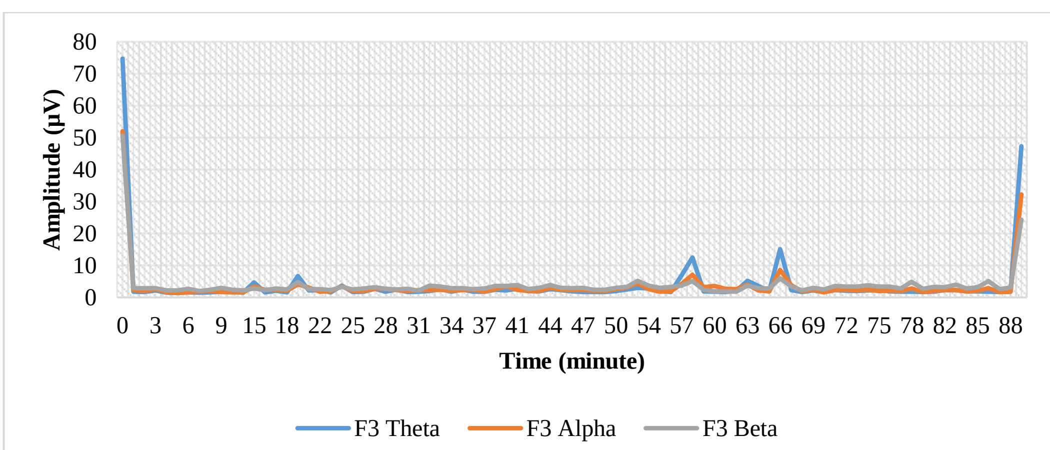


Alpha (8-13 Hz)



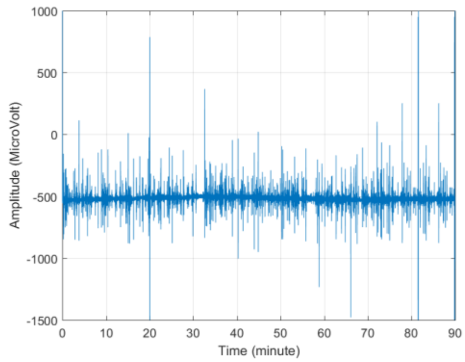
Beta (13-30 Hz)

   b. RMS calculation

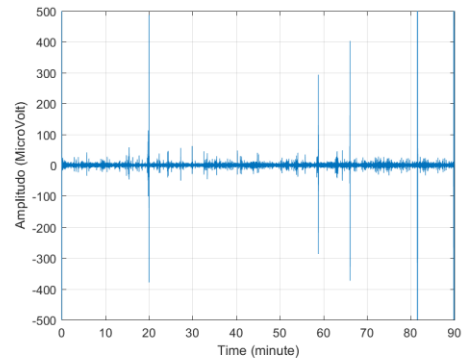


2. F4 channel

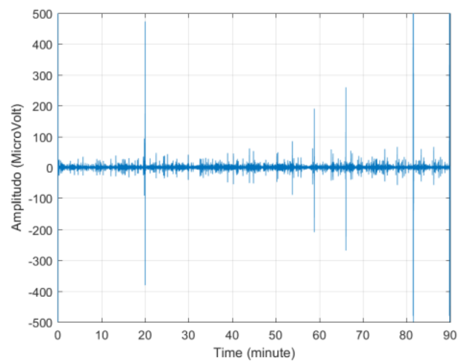
a. EEG Signal



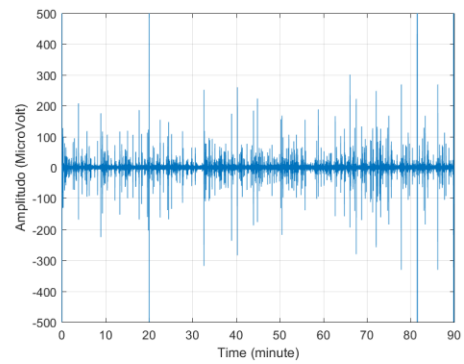
EEG Raw Data



Theta (4-8 Hz)

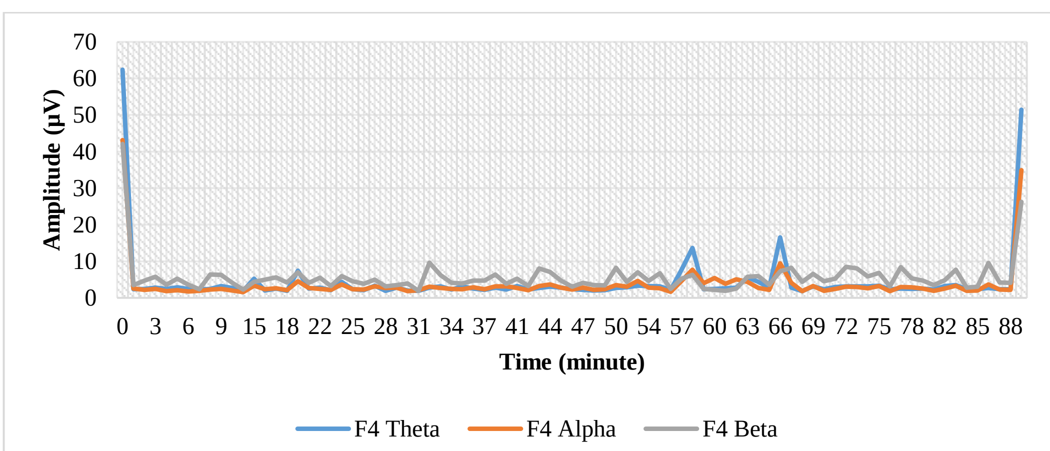


Alpha (8-13 Hz)



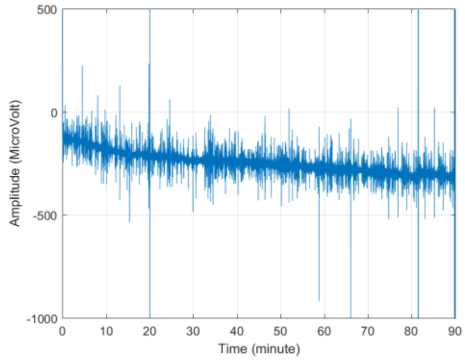
Beta (13-30 Hz)

b. RMS calculation

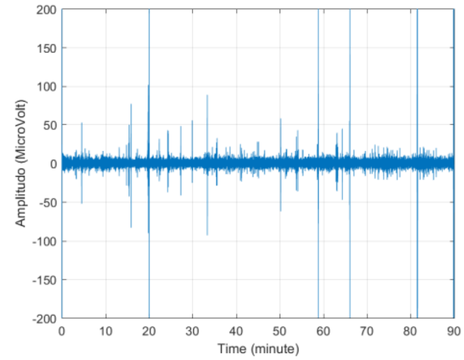


3. P3 channel

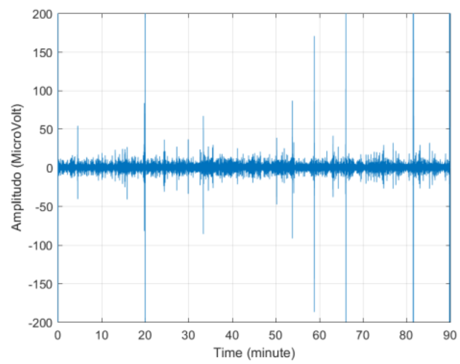
a. EEG Signal



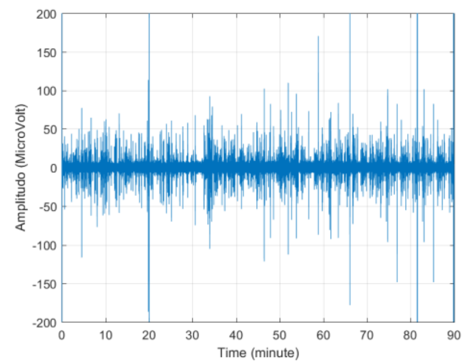
EEG Raw Data



Theta (4-8 Hz)

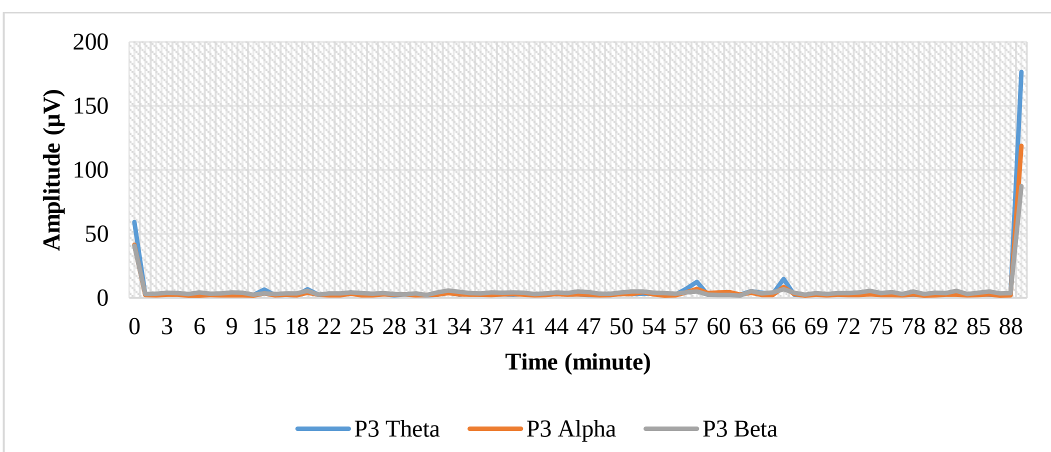


Alpha (8-13 Hz)



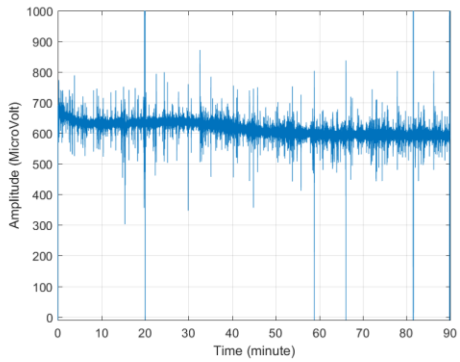
Beta (13-30 Hz)

b. RMS calculation

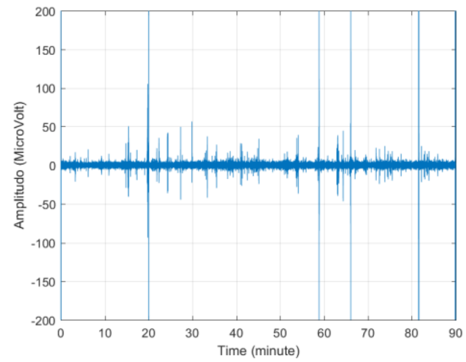


4. P4 channel

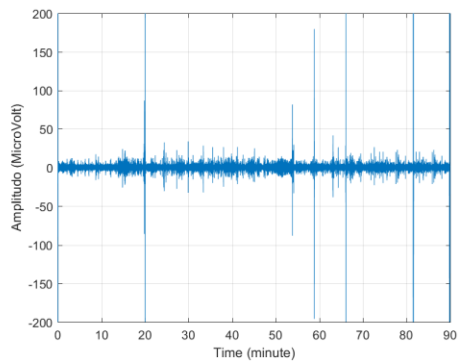
a. EEG Signal



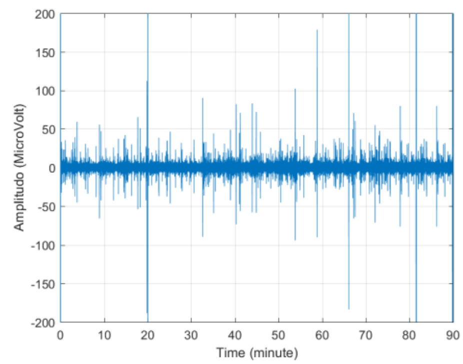
EEG Raw Data



Theta (4-8 Hz)

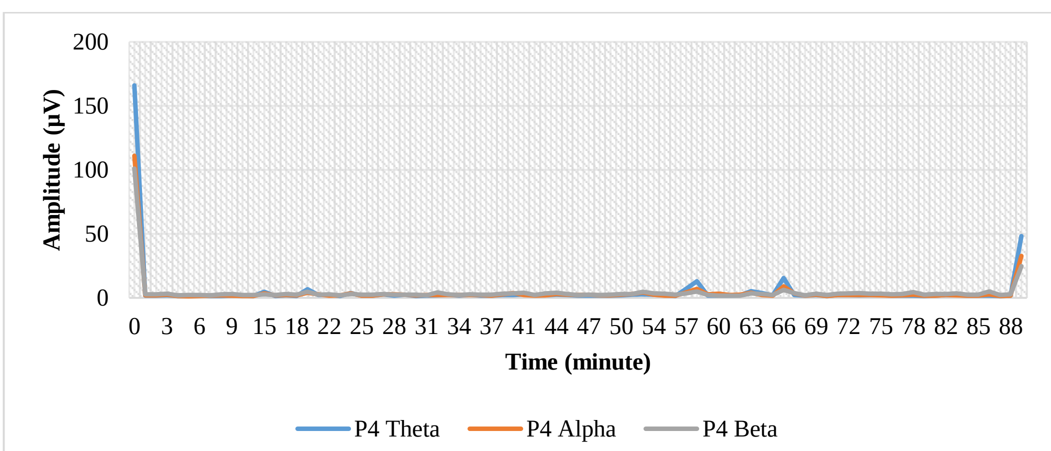


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

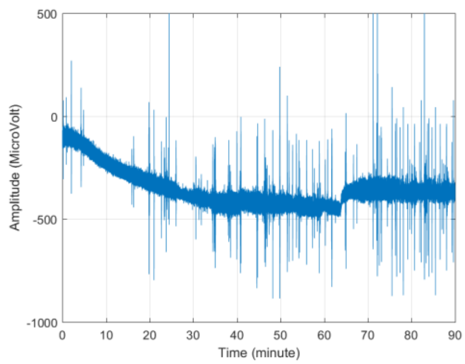


APPENDICES 11

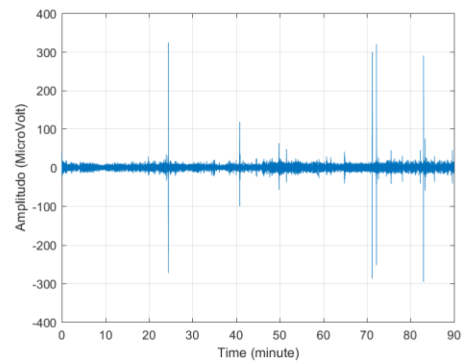
NON-AUTODIDACT IN THE LATE MORNING [PARTICIPANT 3]

1. F3 channel

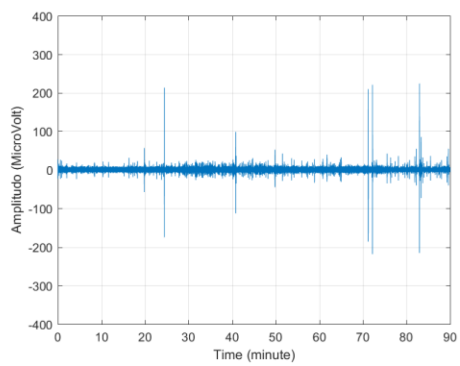
   a. EEG Signal



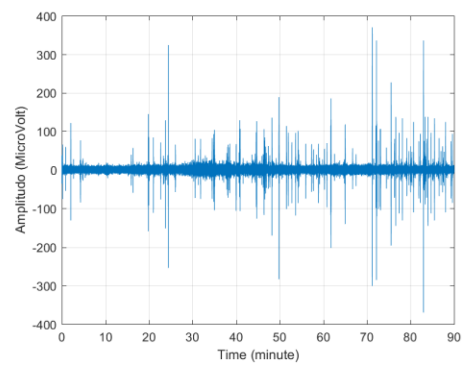
EEG Raw Data



Theta (4-8 Hz)

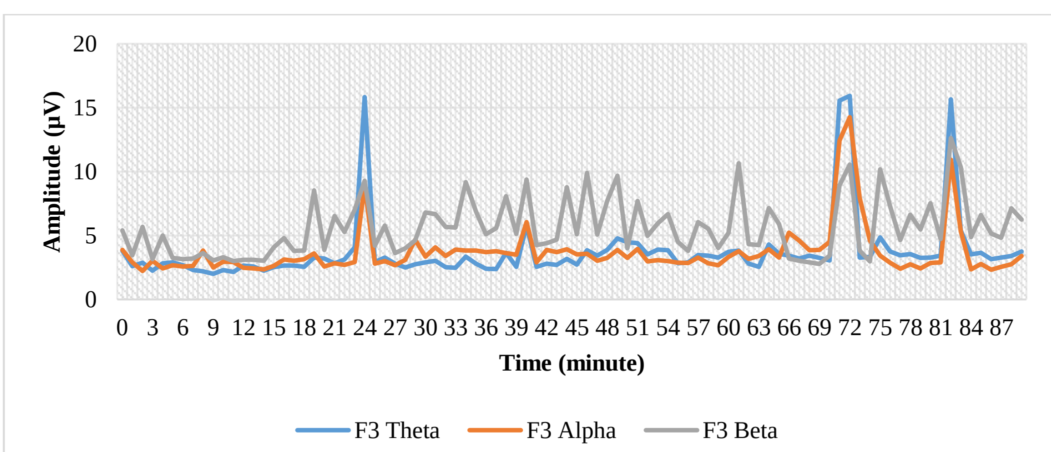


Alpha (8-13 Hz)



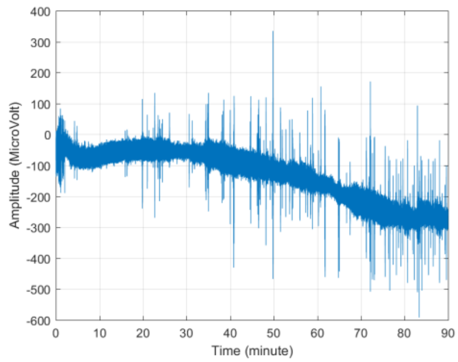
Beta (13-30 Hz)

   b. RMS calculation

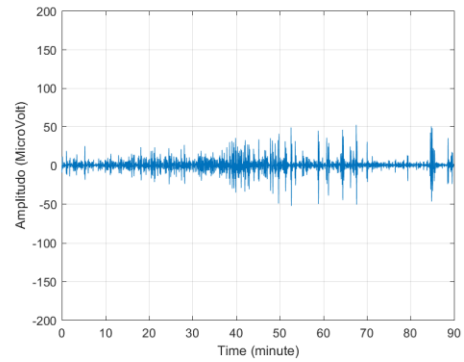


2. F4 channel

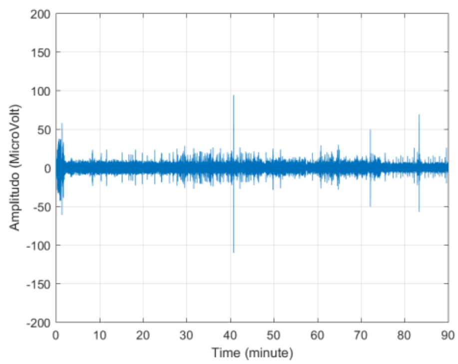
a. EEG Signal



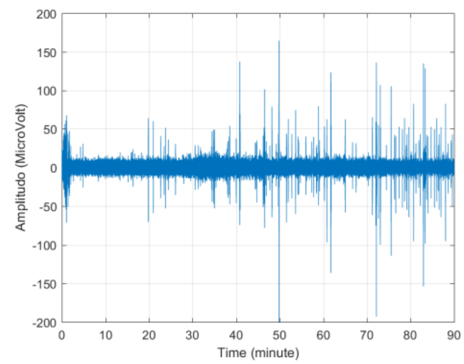
EEG Raw Data



Theta (4-8 Hz)

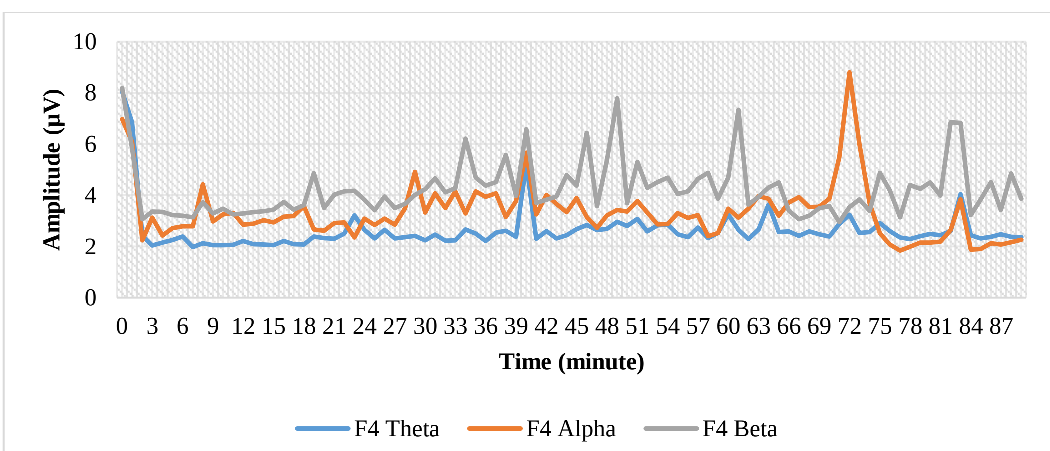


Alpha (8-13 Hz)



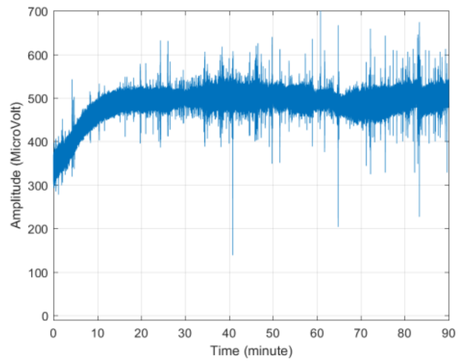
Beta (13-30 Hz)

b. RMS calculation

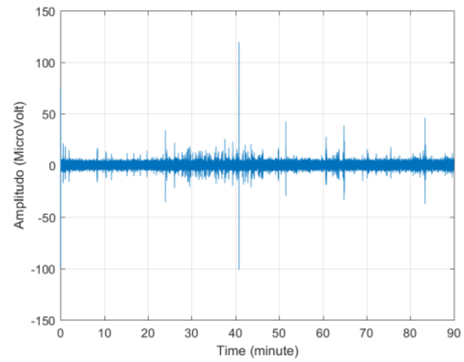


3. P3 channel

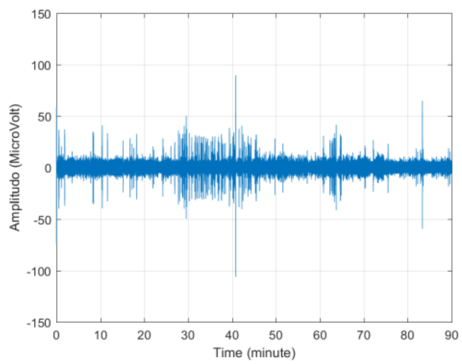
a. EEG Signal



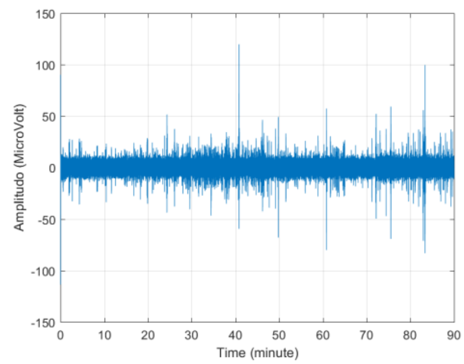
EEG Raw Data



Theta (4-8 Hz)

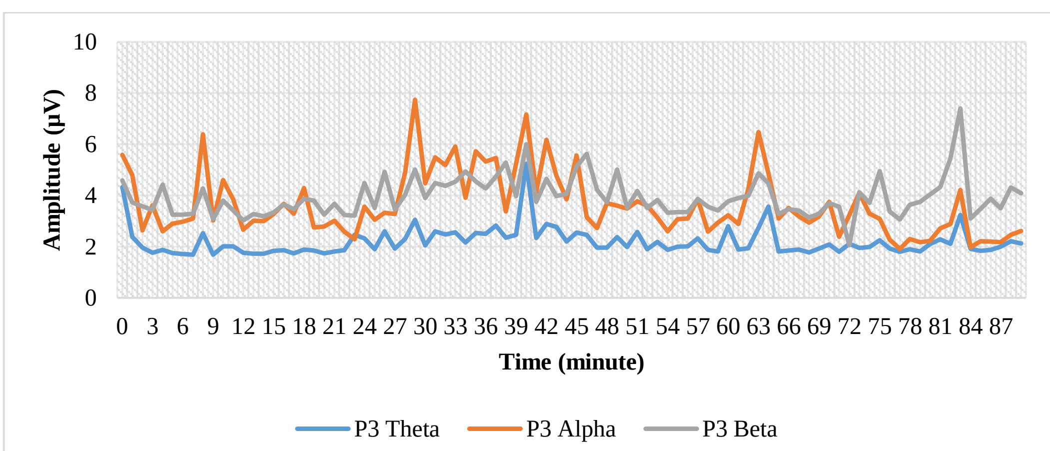


Alpha (8-13 Hz)



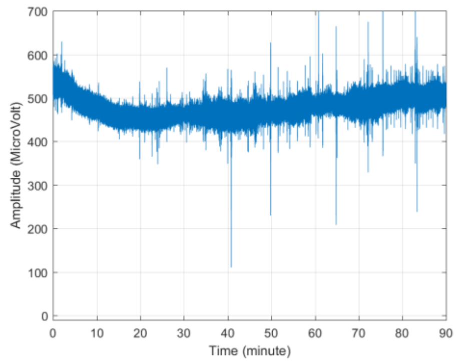
Beta (13-30 Hz)

b. RMS calculation

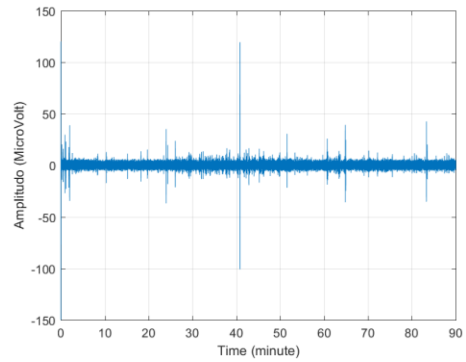


4. P4 channel

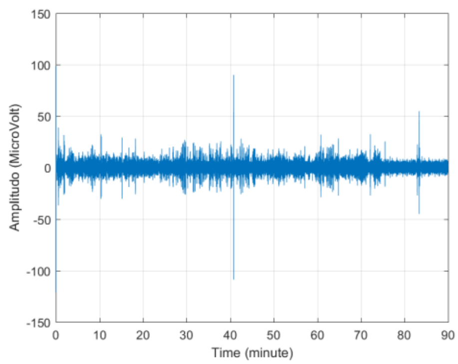
a. EEG Signal



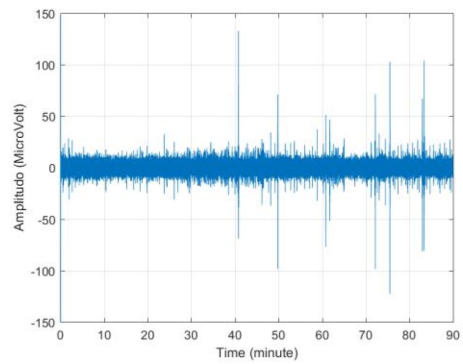
EEG Raw Data



Theta (4-8 Hz)

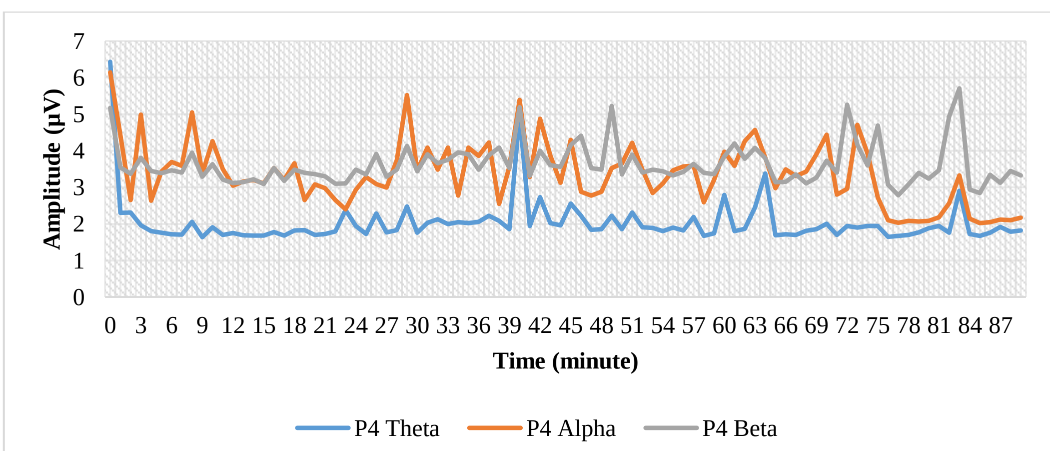


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

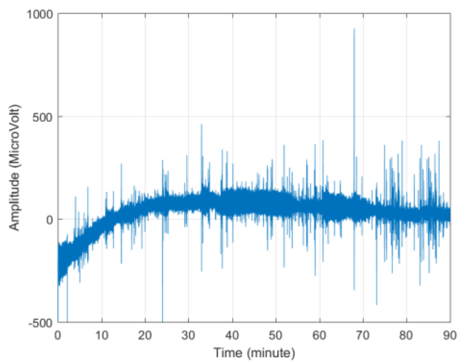


APPENDICES 12

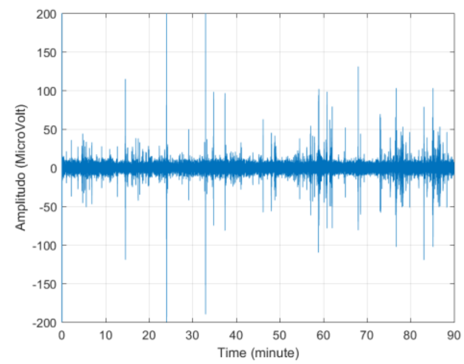
NON-AUTODIDACT IN THE LATE MORNING [PARTICIPANT 4]

1. F3 channel

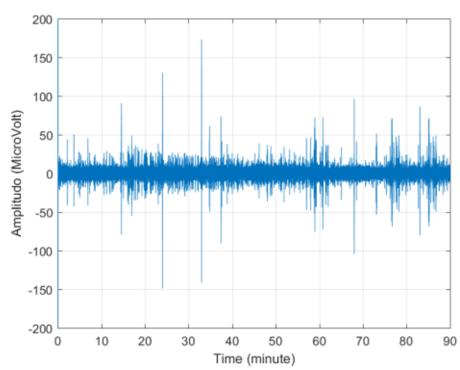
   a. EEG Signal



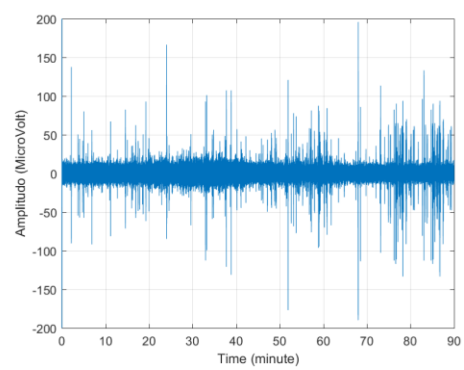
EEG Raw Data



Theta (4-8 Hz)

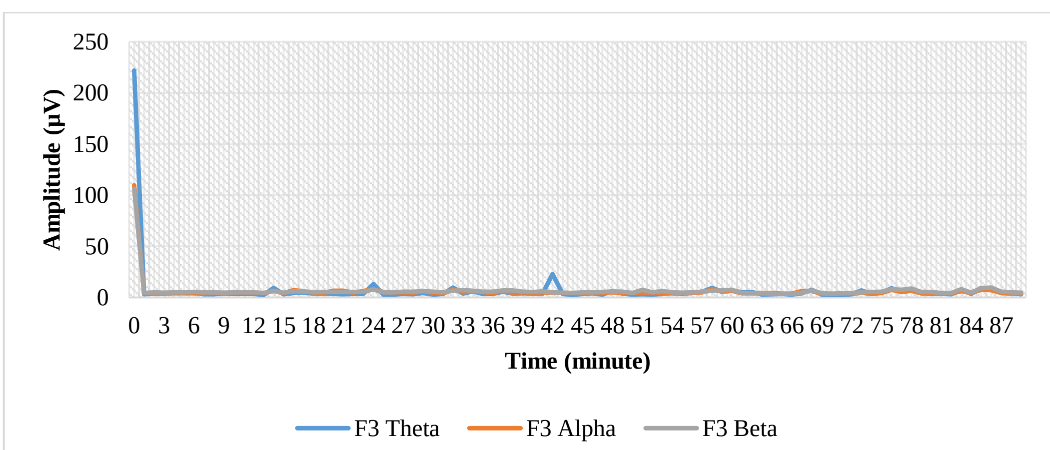


Alpha (8-13 Hz)



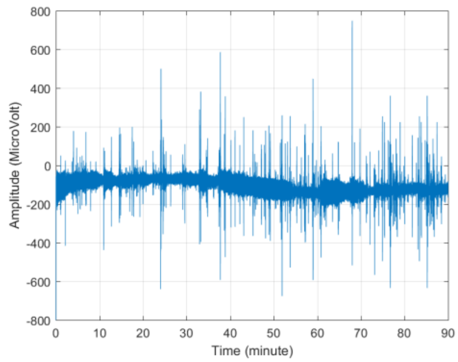
Beta (13-30 Hz)

   b. RMS calculation

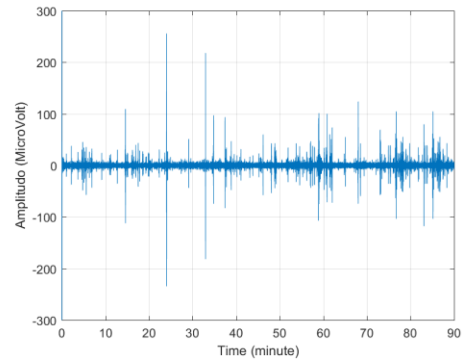


2. F4 channel

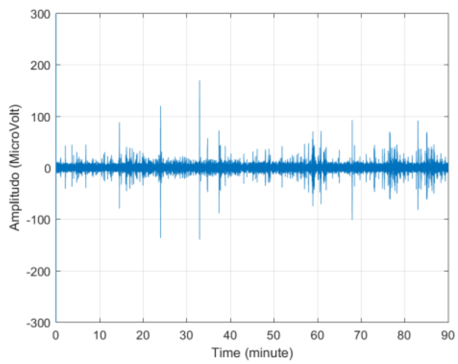
a. EEG Signal



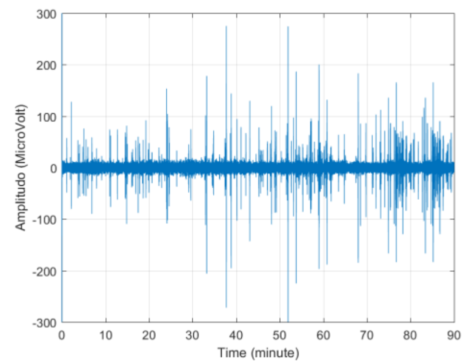
EEG Raw Data



Theta (4-8 Hz)

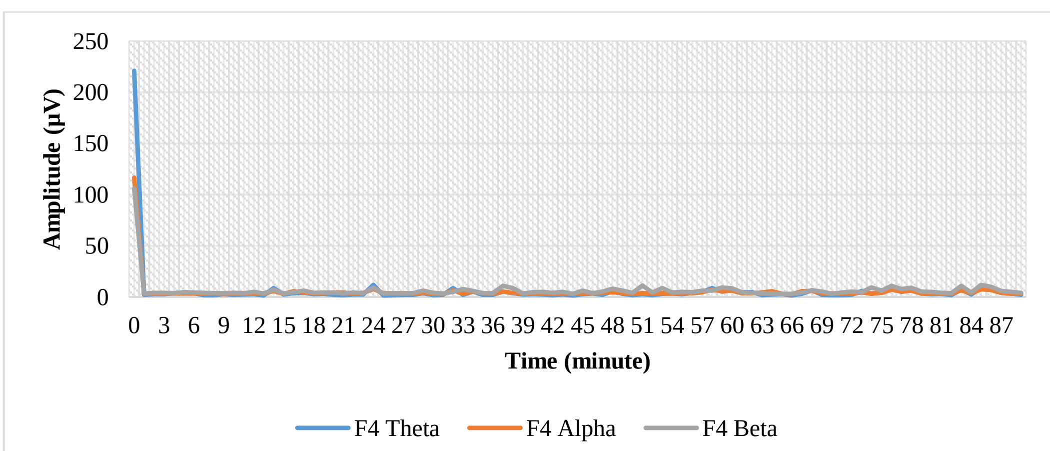


Alpha (8-13 Hz)



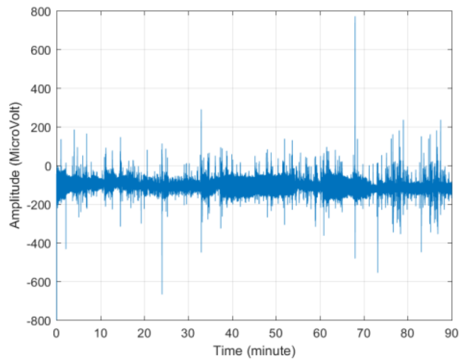
Beta (13-30 Hz)

b. RMS calculation

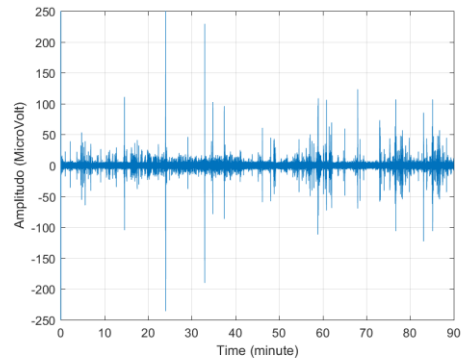


3. P3 channel

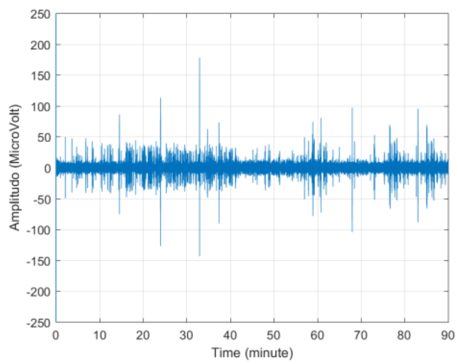
a. EEG Signal



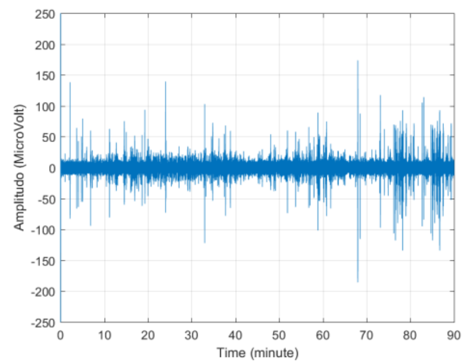
EEG Raw Data



Theta (4-8 Hz)

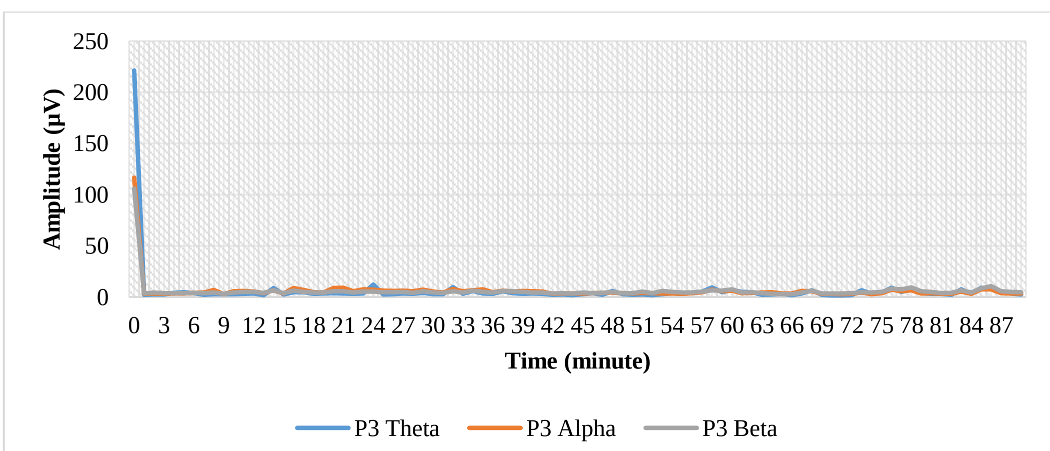


Alpha (8-13 Hz)



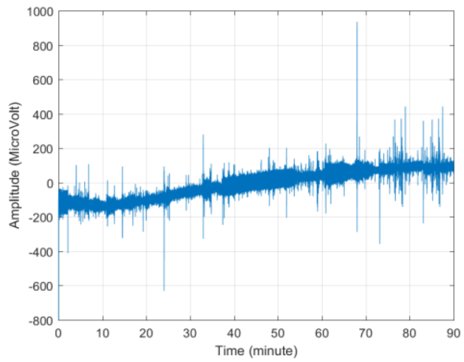
Beta (13-30 Hz)

b. RMS calculation

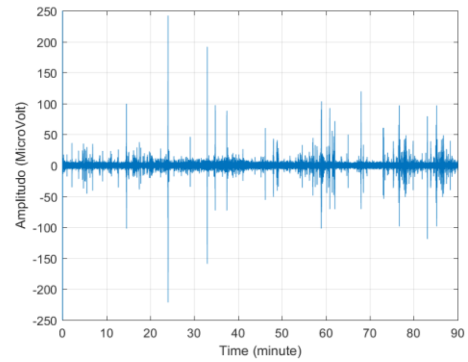


4. P4 channel

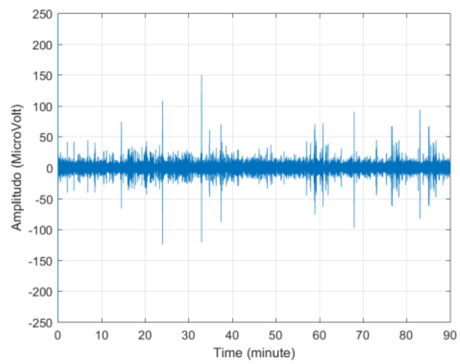
a. EEG Signal



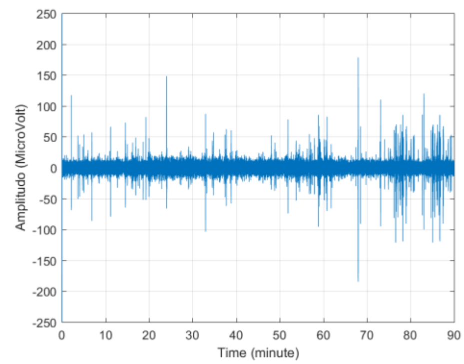
EEG Raw Data



Theta (4-8 Hz)

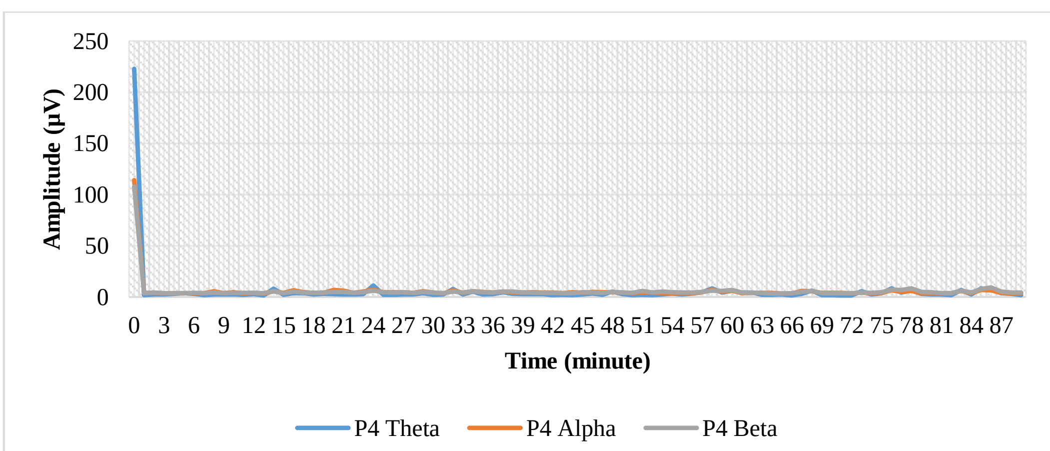


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

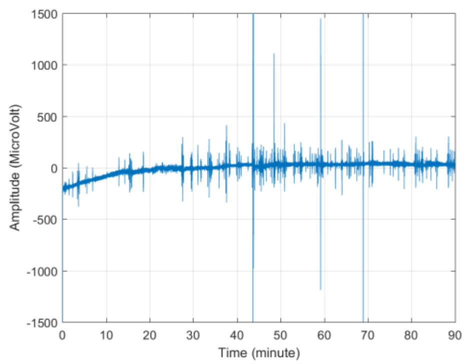


APPENDICES 13

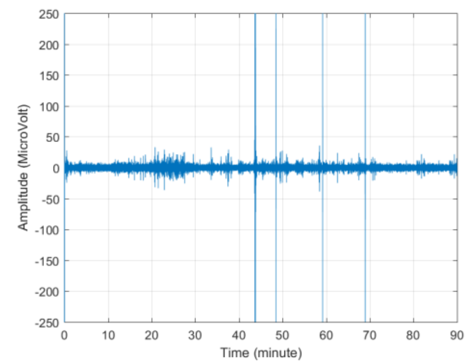
NON-AUTODIDACT IN THE AFTERNOON [PARTICIPANT 1]

1. F3 channel

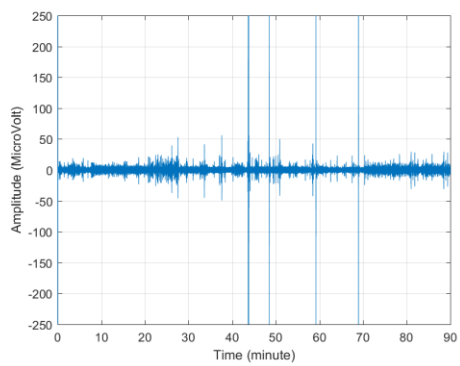
   a. EEG Signal



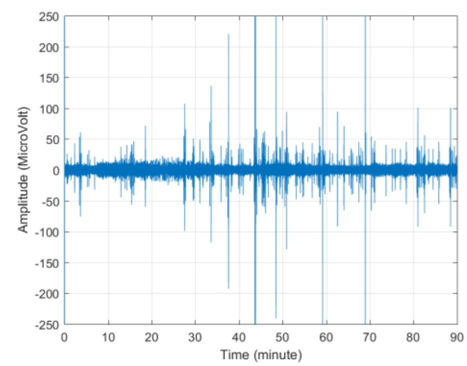
EEG Raw Data



Theta (4-8 Hz)

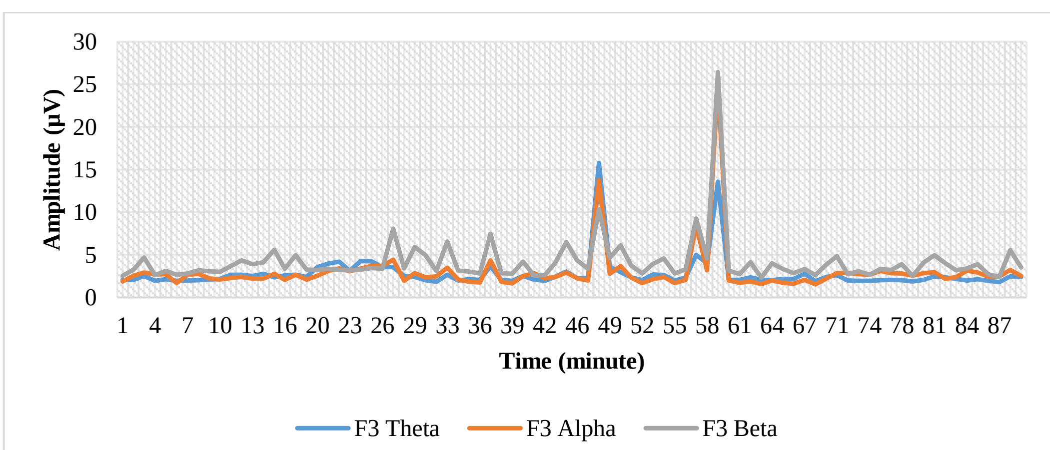


Alpha (8-13 Hz)



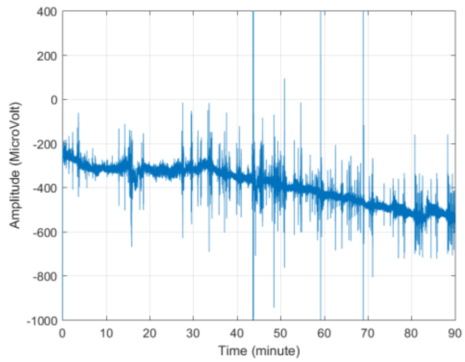
Beta (13-30 Hz)

   b. RMS calculation

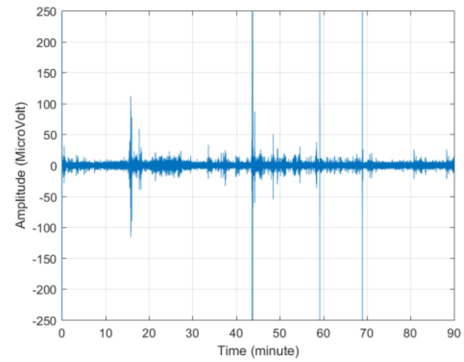


2. F4 channel

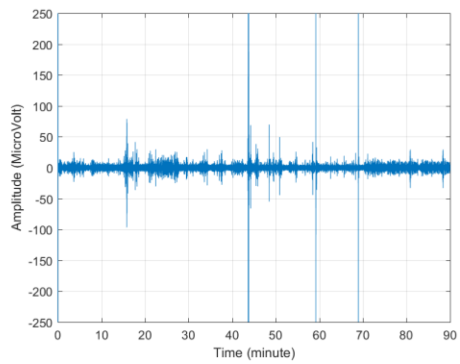
a. EEG Signal



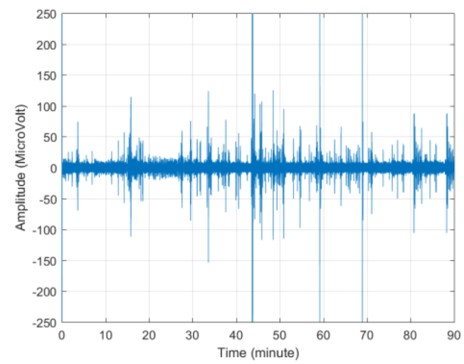
EEG Raw Data



Theta (4-8 Hz)

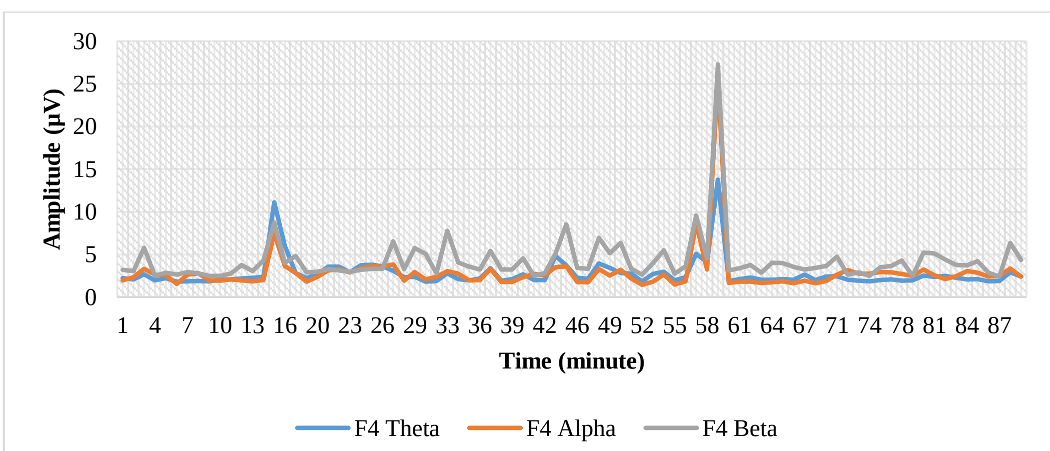


Alpha (8-13 Hz)



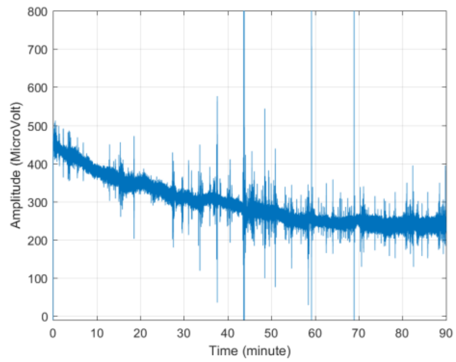
Beta (13-30 Hz)

b. RMS calculation

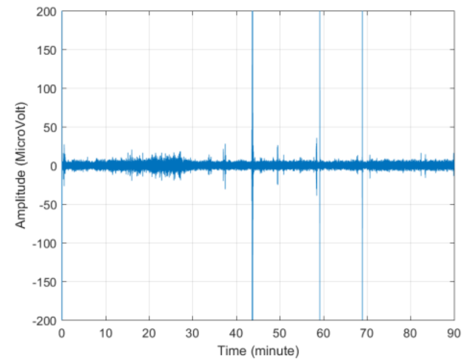


3. P3 channel

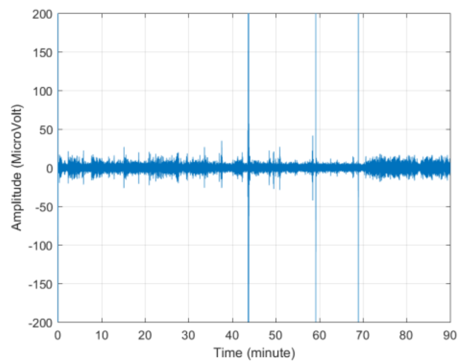
a. EEG Signal



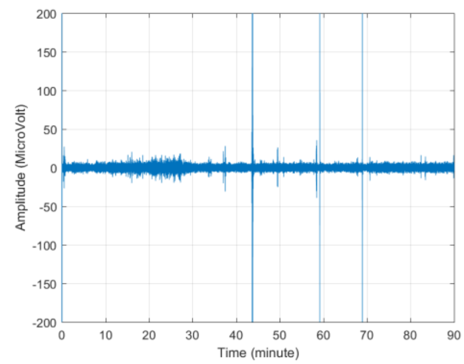
EEG Raw Data



Theta (4-8 Hz)

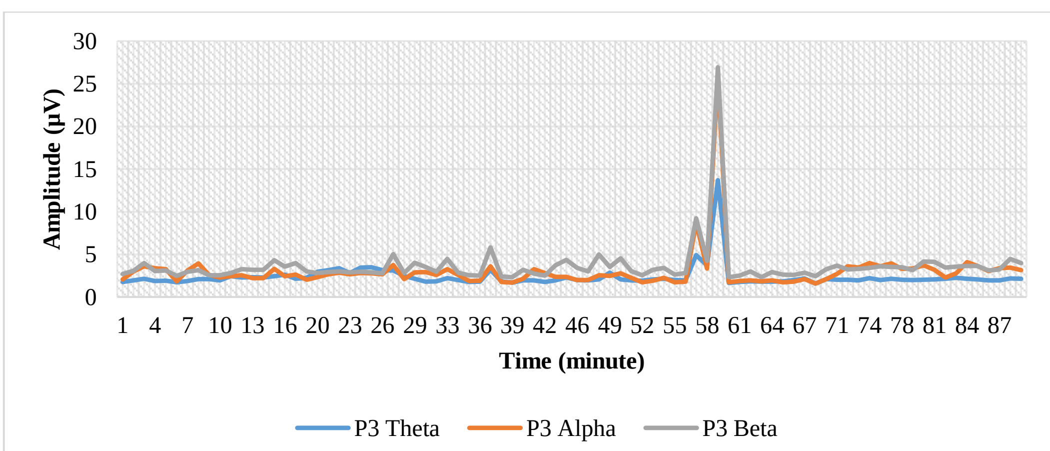


Alpha (8-13 Hz)



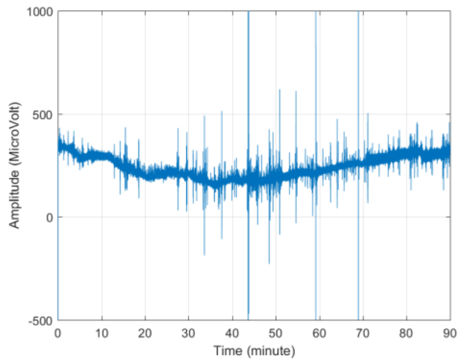
Beta (13-30 Hz)

b. RMS calculation

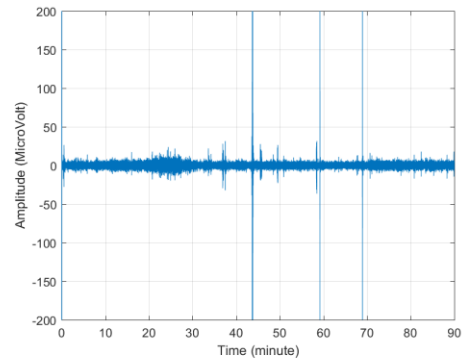


4. P4 channel

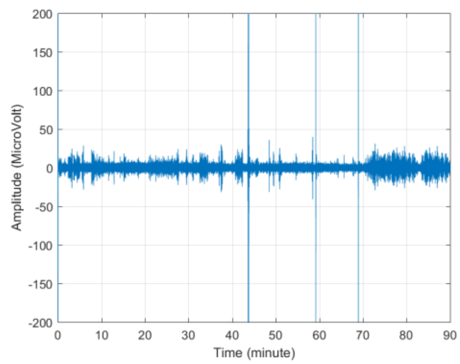
   a. EEG Signal



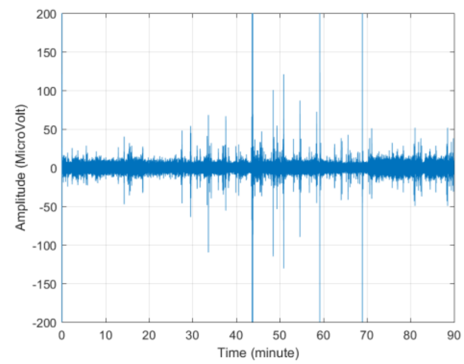
EEG Raw Data



Theta (4-8 Hz)

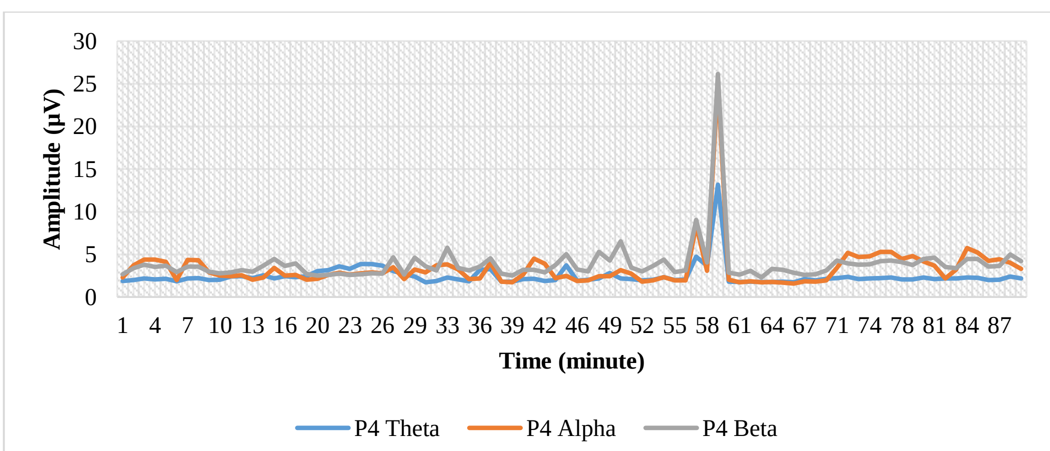


Alpha (8-13 Hz)



Beta (13-30 Hz)

   b. RMS calculation

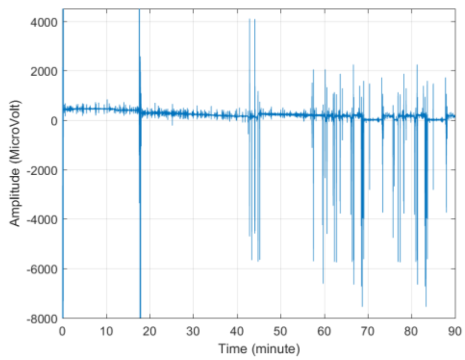


APPENDICES 14

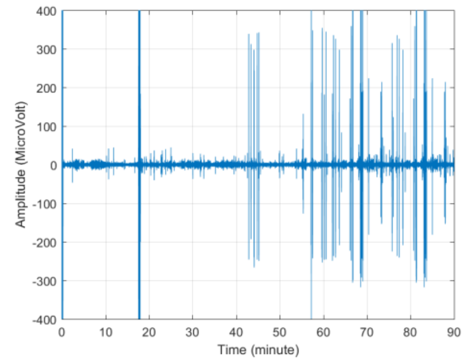
NON-AUTODIDACT IN THE AFTERNOON [PARTICIPANT 2]

1. F3 channel

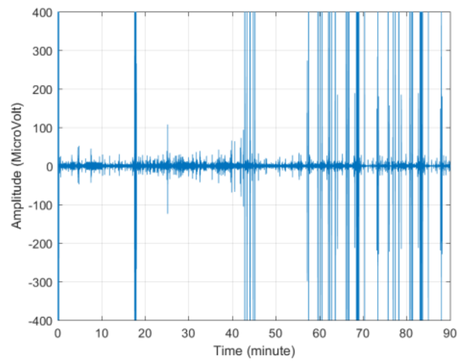
a. EEG Signal



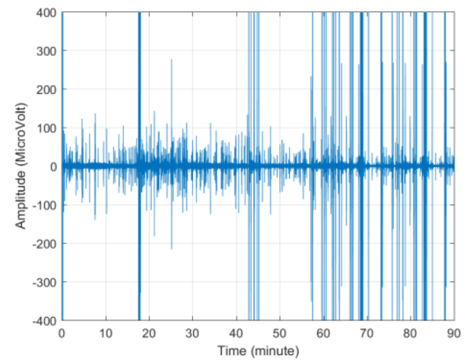
EEG Raw Data



Theta (4-8 Hz)

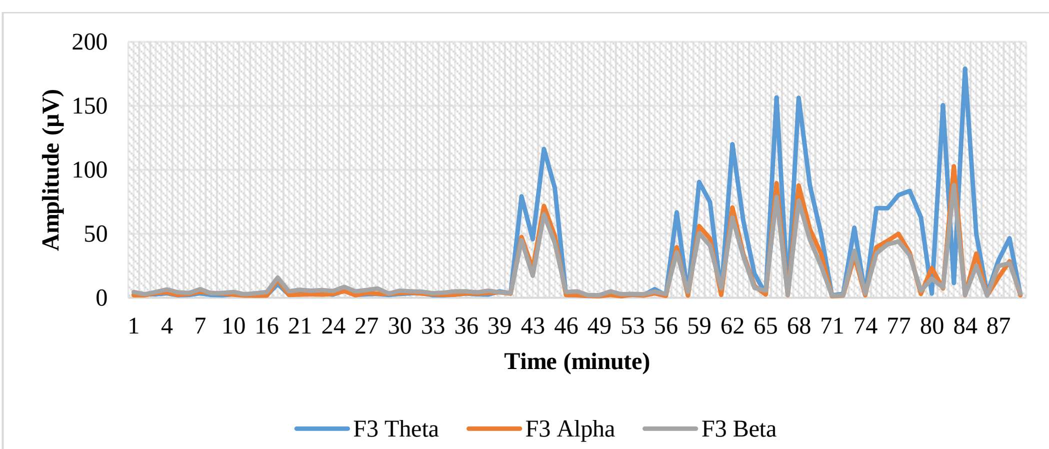


Alpha (8-13 Hz)



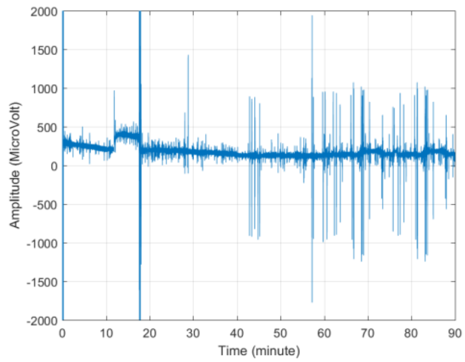
Beta (13-30 Hz)

b. RMS calculation

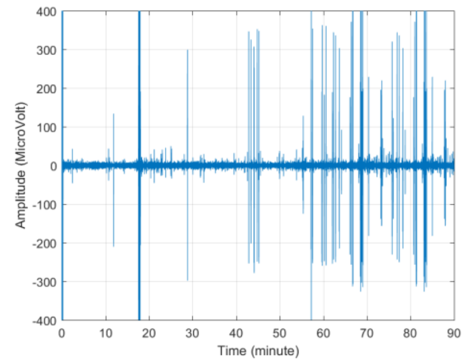


2. F4 channel

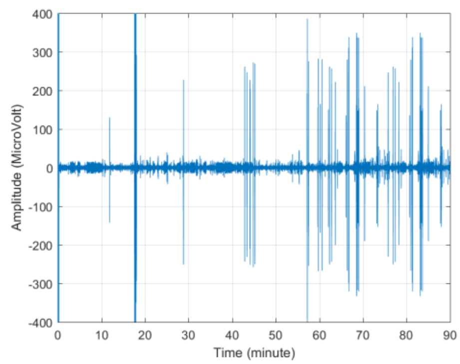
a. EEG Signal



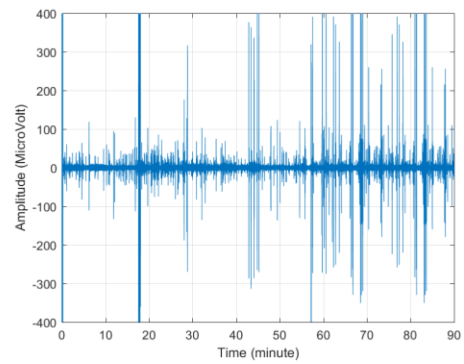
EEG Raw Data



Theta (4-8 Hz)

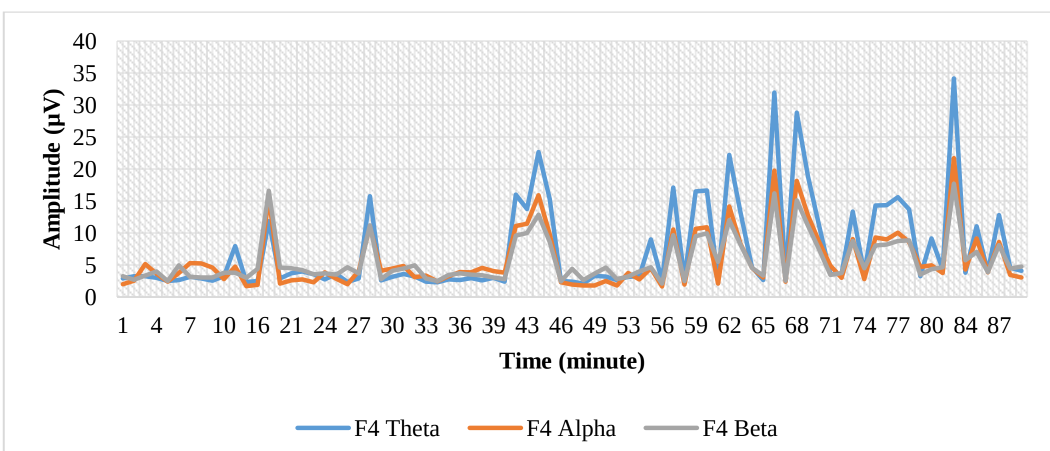


Alpha (8-13 Hz)



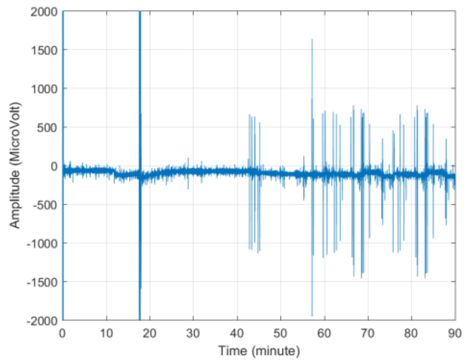
Beta (13-30 Hz)

b. RMS calculation

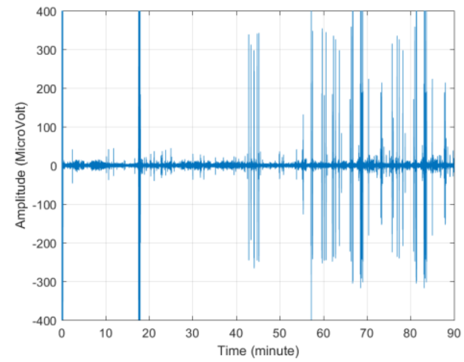


3. P3 channel

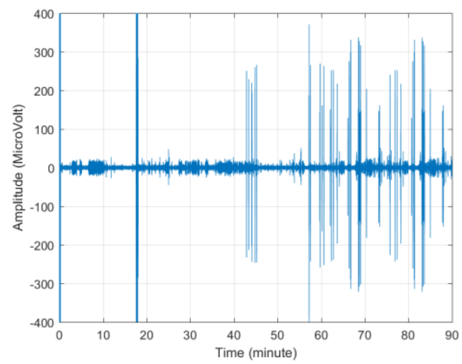
a. EEG Signal



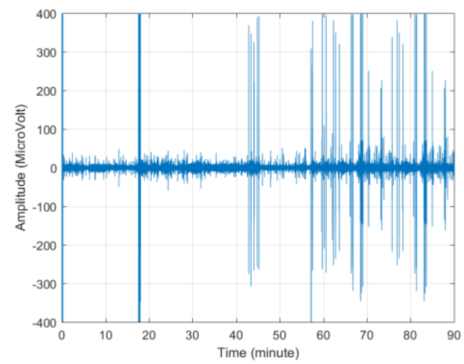
EEG Raw Data



Theta (4-8 Hz)

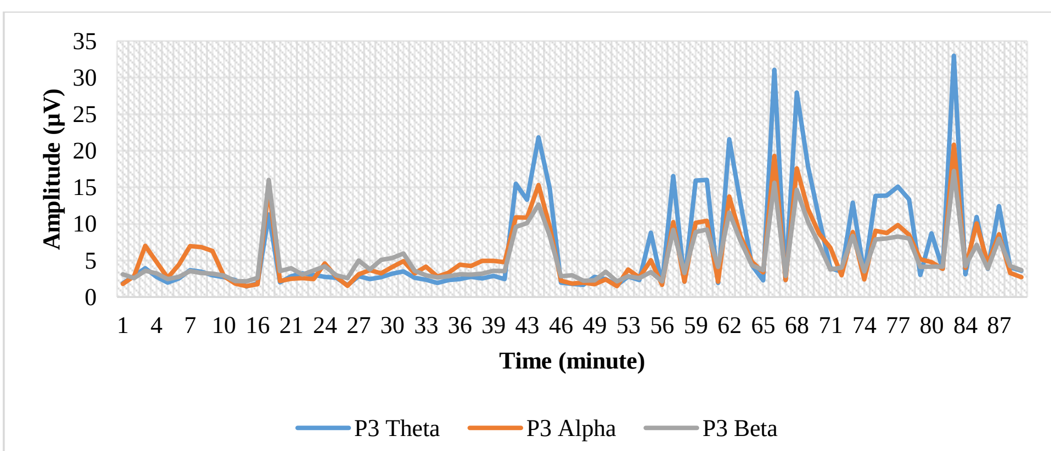


Alpha (8-13 Hz)



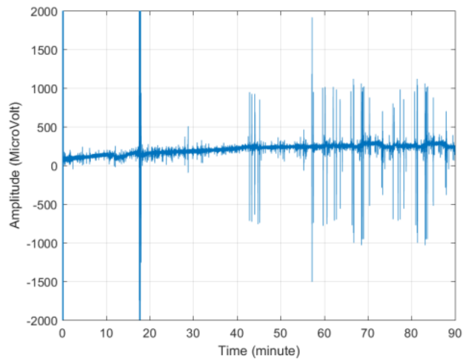
Beta (13-30 Hz)

b. RMS calculation

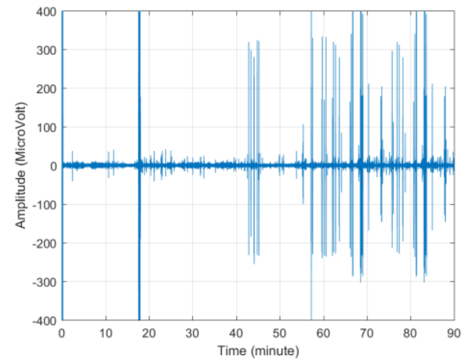


4. P4 channel

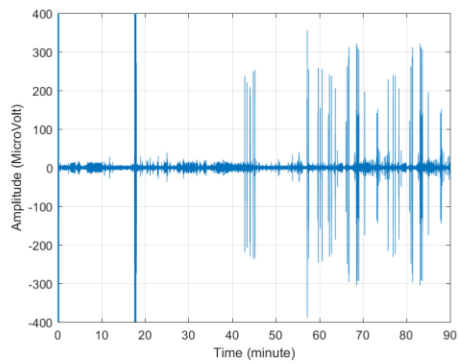
a. EEG Signal



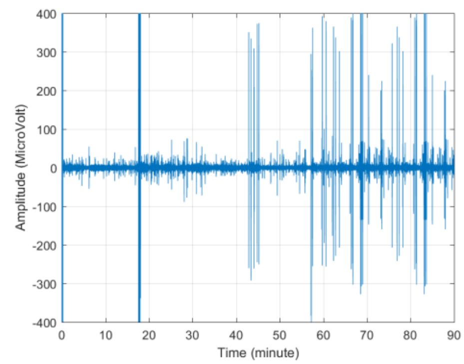
EEG Raw Data



Theta (4-8 Hz)

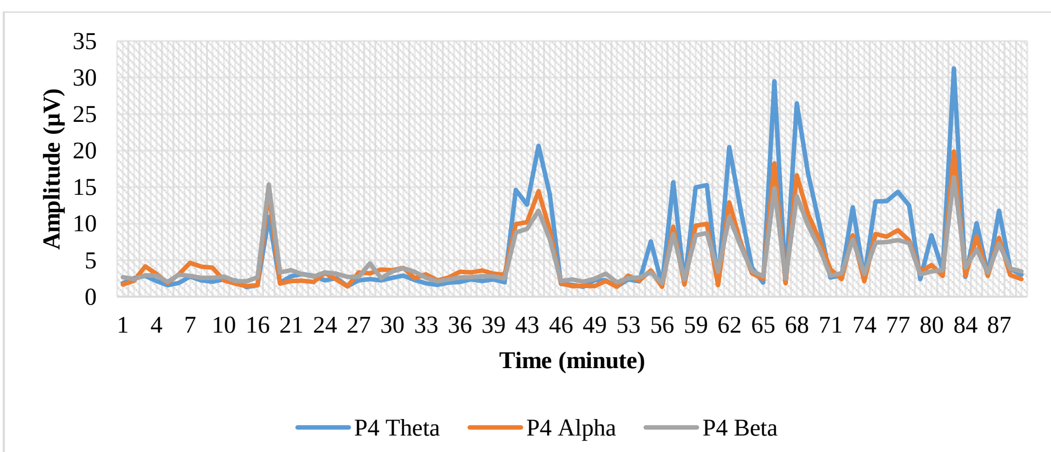


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

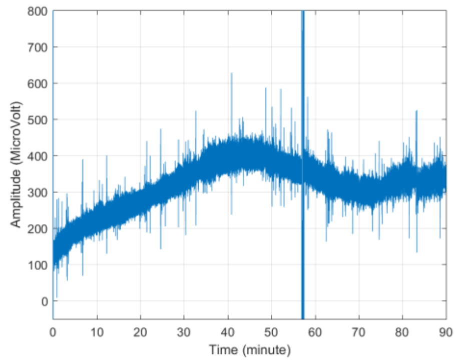


APPENDICES 15

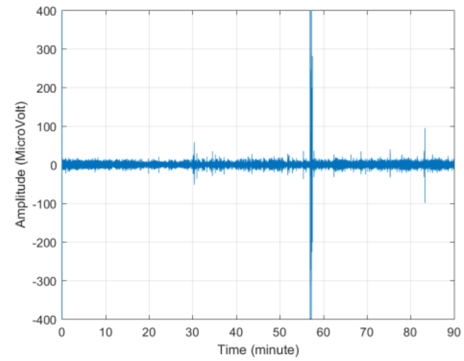
NON-AUTODIDACT IN THE AFTERNOON [PARTICIPANT 3]

1. F3 channel

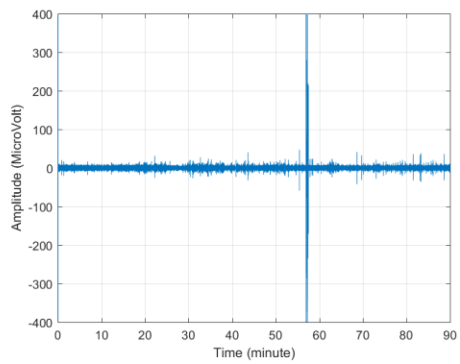
   a. EEG Signal



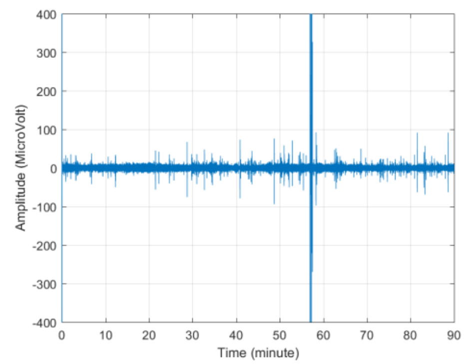
EEG Raw Data



Theta (4-8 Hz)

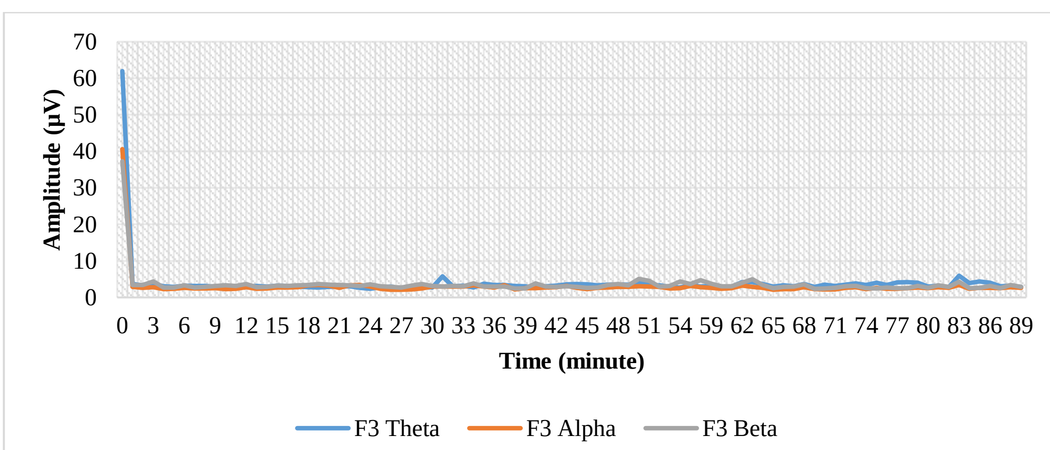


Alpha (8-13 Hz)



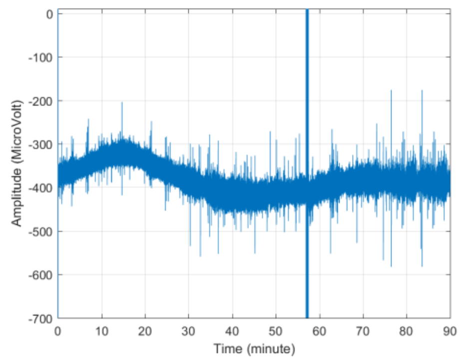
Beta (13-30 Hz)

   b. RMS calculation

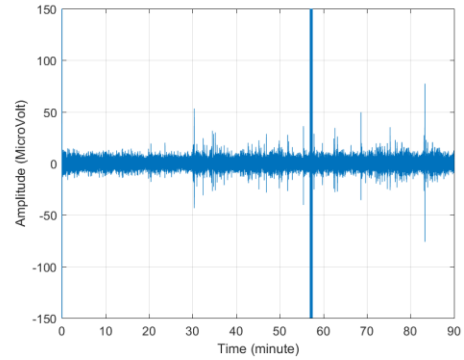


2. F4 channel

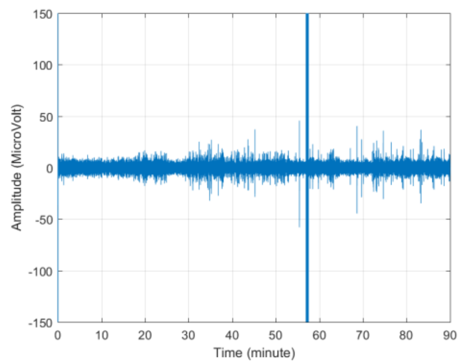
a. EEG Signal



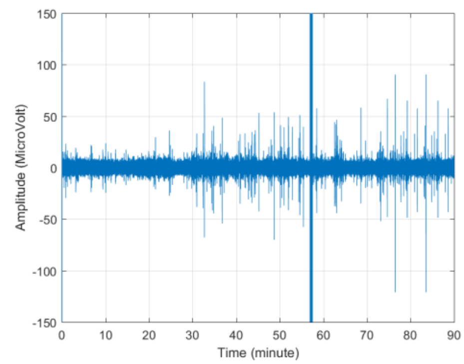
EEG Raw Data



Theta (4-8 Hz)

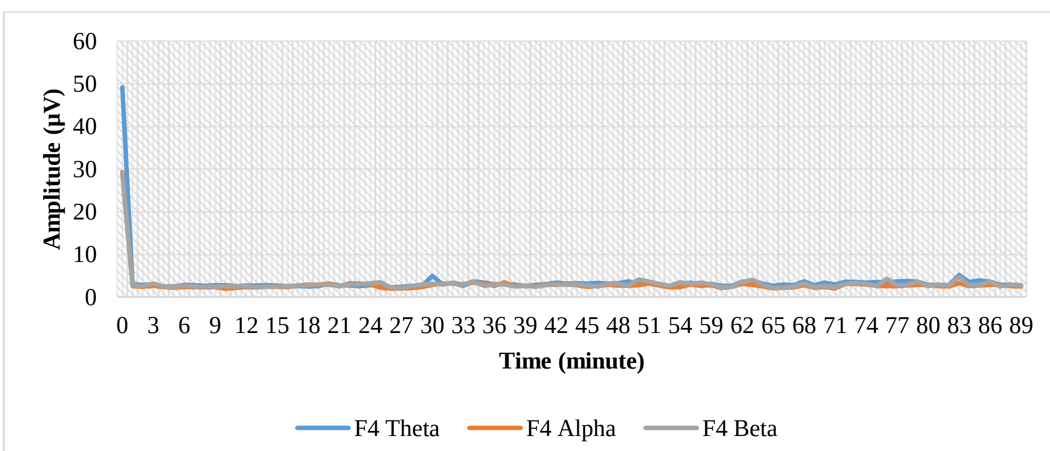


Alpha (8-13 Hz)



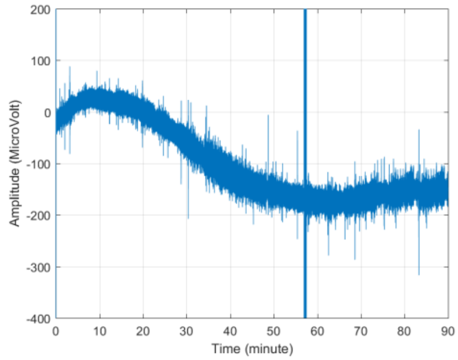
Beta (13-30 Hz)

b. RMS calculation

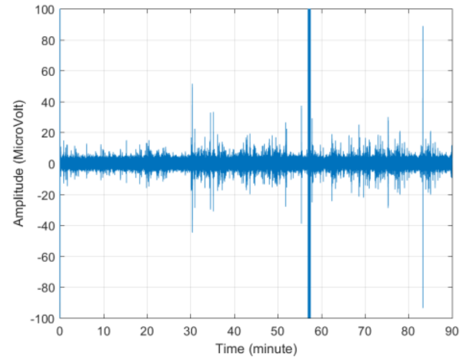


3. P3 channel

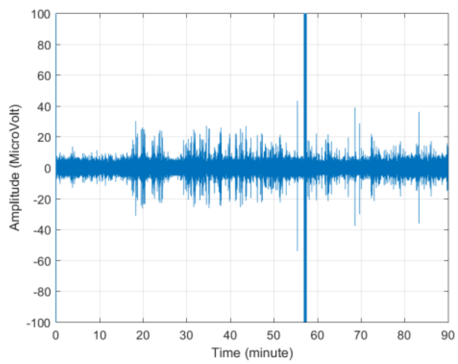
a. EEG Signal



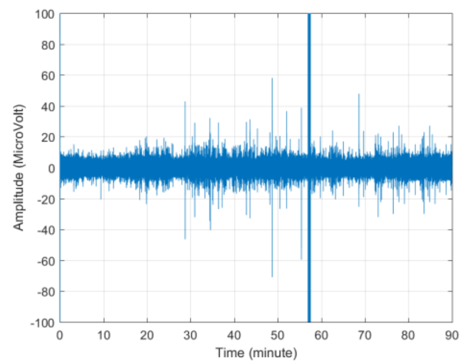
EEG Raw Data



Theta (4-8 Hz)

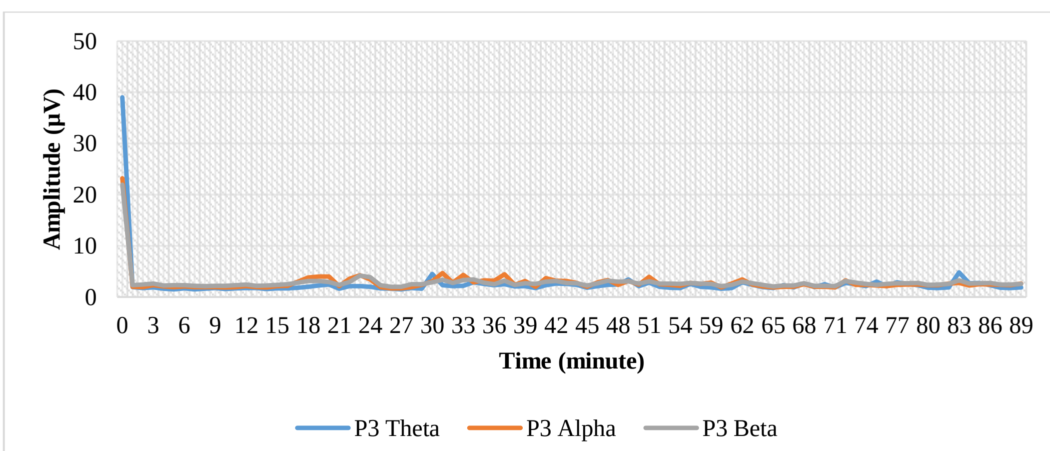


Alpha (8-13 Hz)



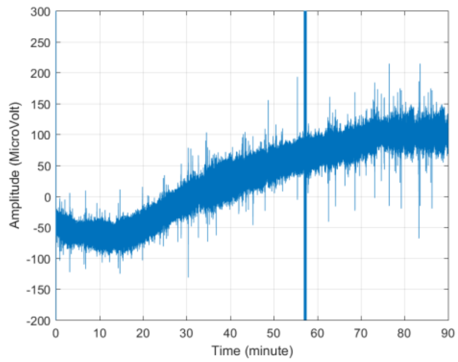
Beta (13-30 Hz)

b. RMS calculation

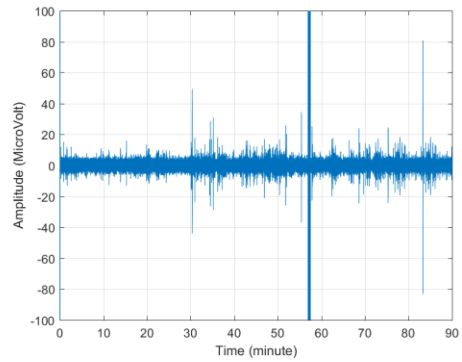


4. P4 channel

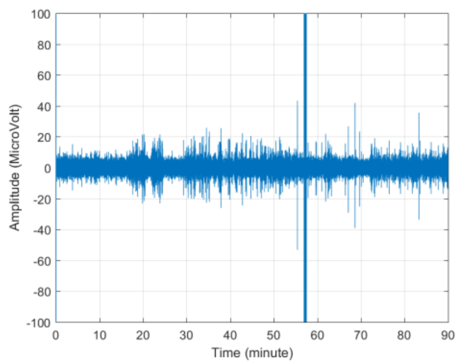
a. EEG Signal



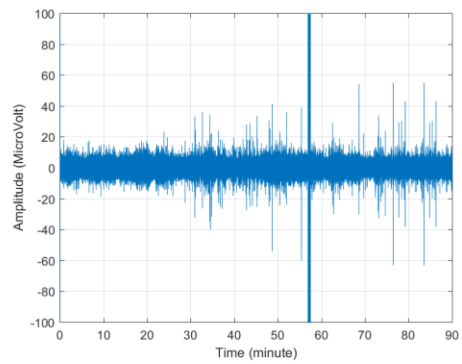
EEG Raw Data



Theta (4-8 Hz)

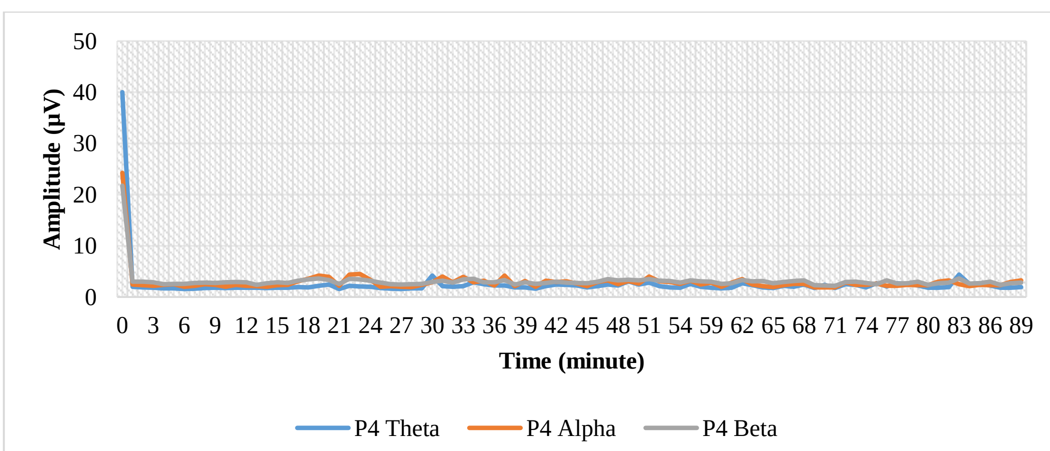


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation

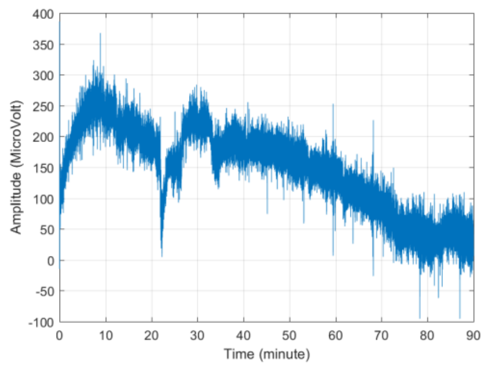


APPENDICES 16

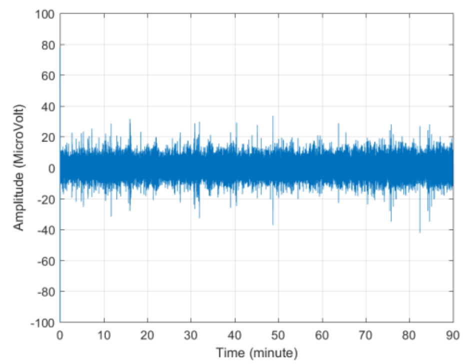
NON-AUTODIDACT IN THE AFTERNOON [PARTICIPANT 4]

1. F3 channel

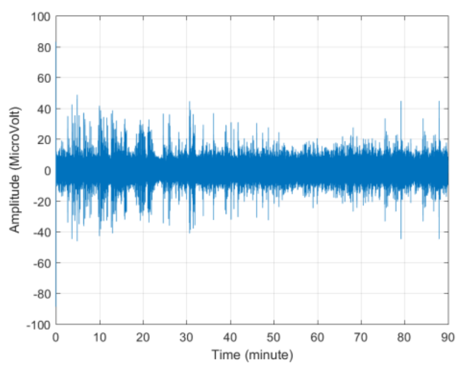
   a. EEG Signal



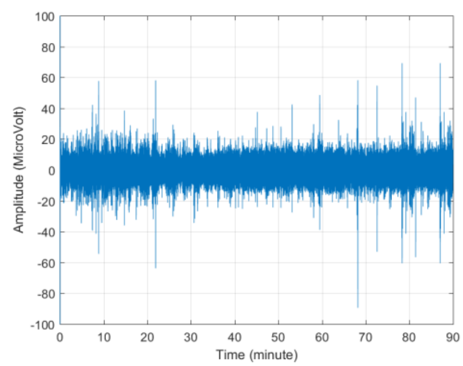
EEG Raw Data



Theta (4-8 Hz)

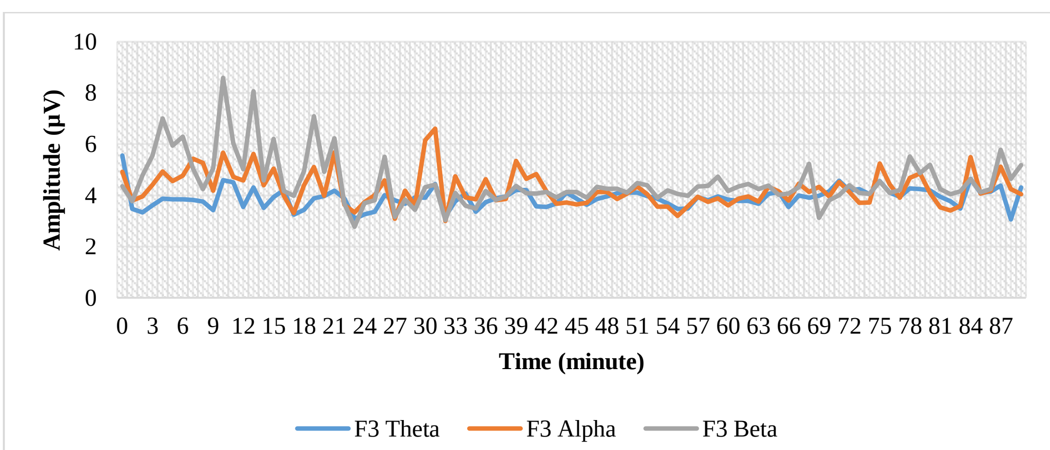


Alpha (8-13 Hz)



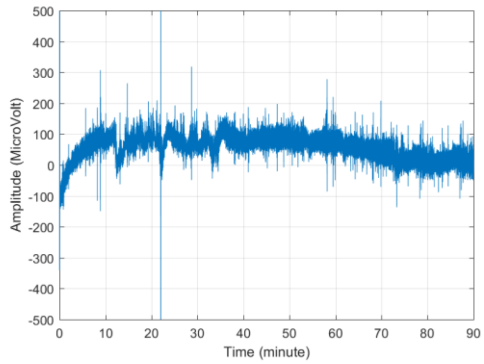
Beta (13-30 Hz)

   b. RMS calculation

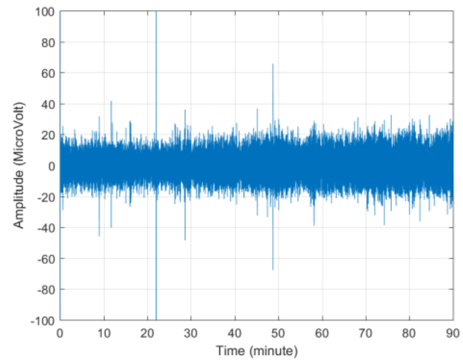


2. F4 channel

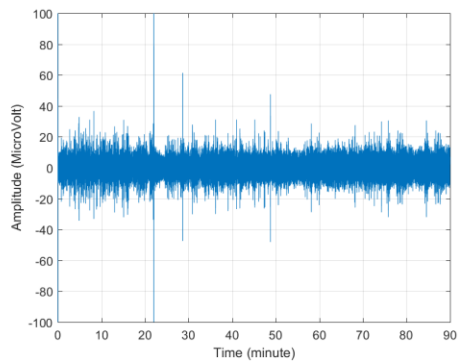
a. EEG Signal



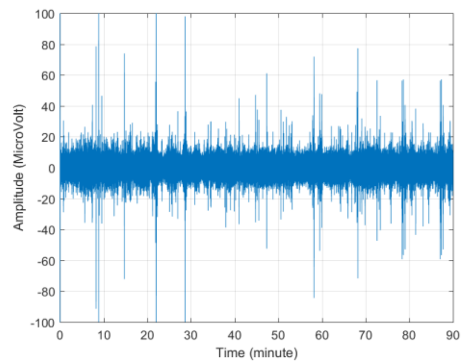
EEG Raw Data



Theta (4-8 Hz)

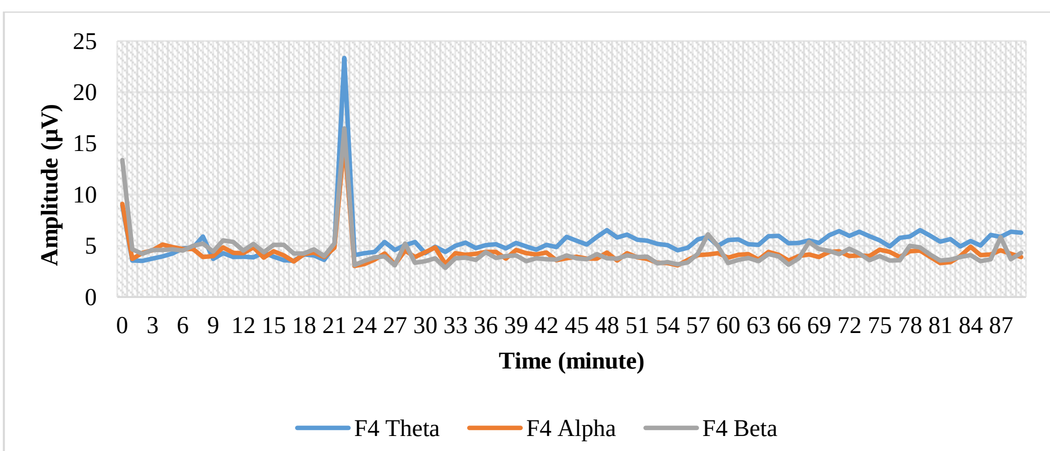


Alpha (8-13 Hz)



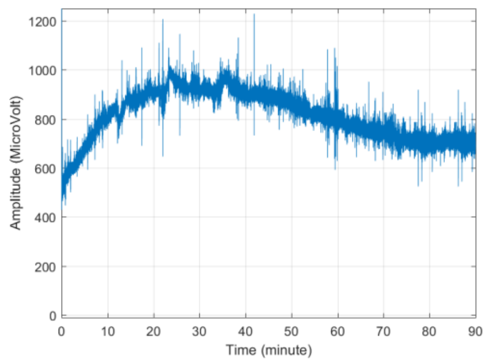
Beta (13-30 Hz)

b. RMS calculation

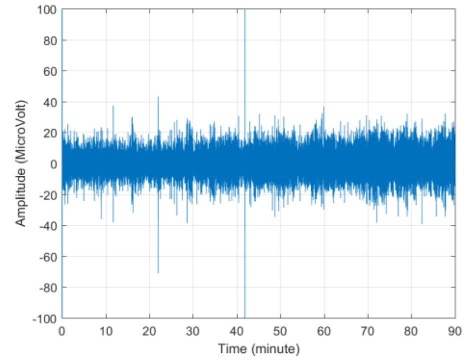


3. P3 channel

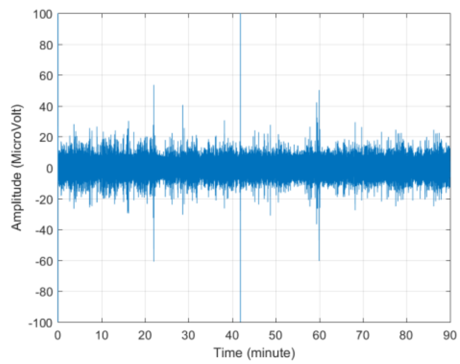
a. EEG Signal



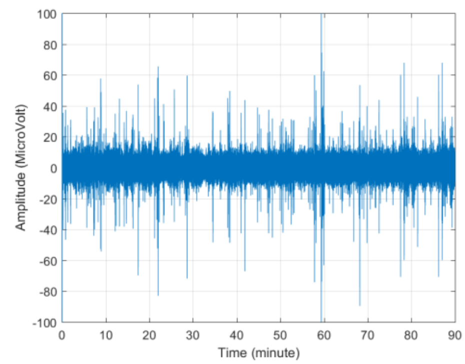
EEG Raw Data



Theta (4-8 Hz)

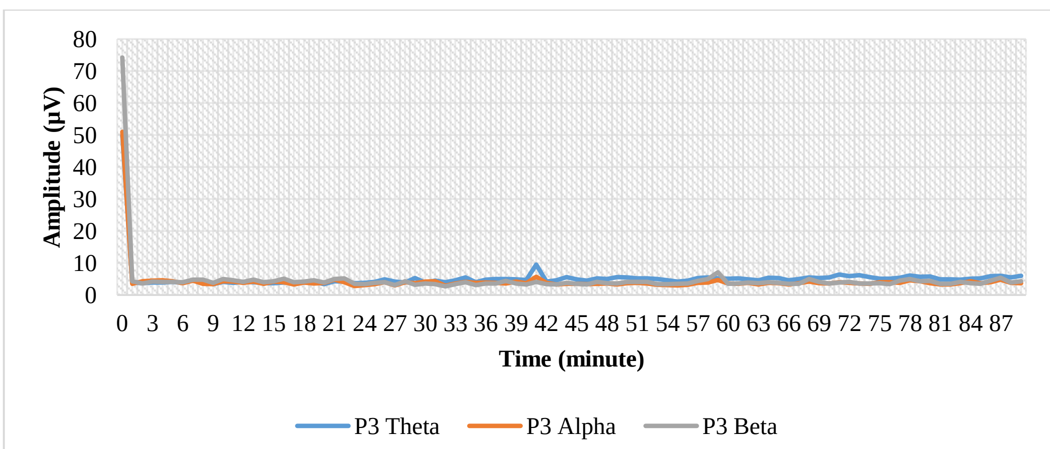


Alpha (8-13 Hz)



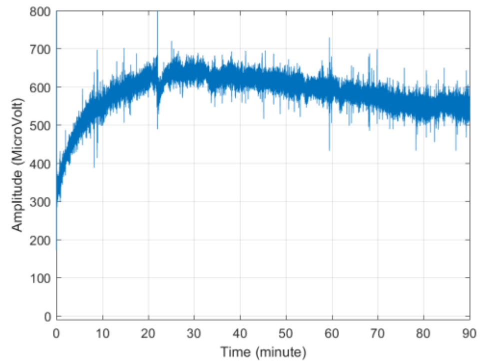
Beta (13-30 Hz)

b. RMS calculation

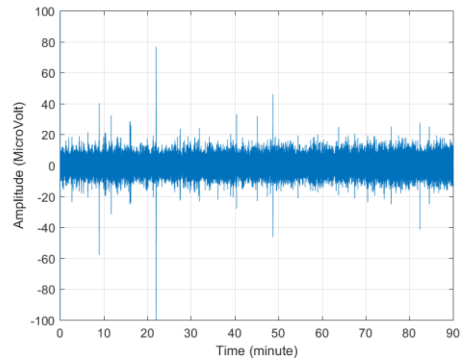


4. P4 channel

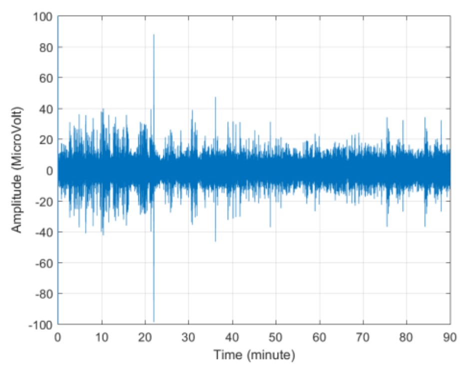
a. EEG Signal



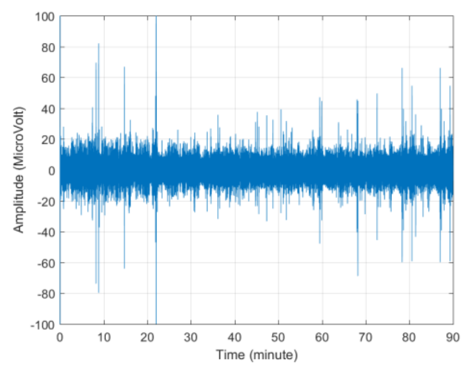
EEG Raw Data



Theta (4-8 Hz)

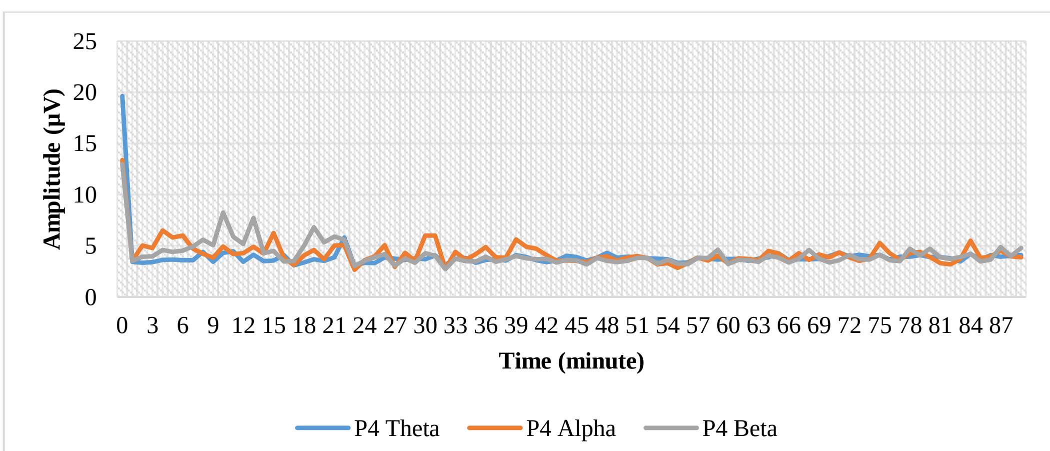


Alpha (8-13 Hz)



Beta (13-30 Hz)

b. RMS calculation



APPENDICES 17

INTERVIEW PROTOCOL FOR PHYSICS TEACHER

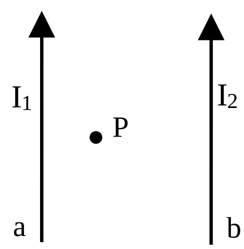
1. Researcher introduction.
2. Research project introduction
3. Interview
   a. Bagaimana sistem pembelajaran Fisika pada sekolah ini? Siapa yang bertanggung jawab mengatur jadwal pelajaran Fisika? Berapa sering siswa menerima pelajaran Fisika dalam satu minggu? Pada waktu kapan pelajaran Fisika dijadwalkan? Berapa lama waktu yang disediakan oleh sekolah untuk kegiatan mengajar Fisika? (How is the system of Physics learning in this school? Who has a responsibility to arrange Physics schedule in this school? How often do students learn Physics in a week? At what time of Physics lesson is scheduled?)
   b. Bagaaimana cara atau metode yang Anda gunakan untuk mengajar Fisika? (How is the method used for teaching the Physics?)
   c. Bagaimana respon siswa ketika Anda mengajar Fisika? (How is student's respond while you are teaching the Physics?)
   d. Menurut Anda, faktor apa yang mempengaruhi hasil belajar siswa khususnya hasil belajar ujian nasional? (In your opinion, what is factor contributing the student learning result especially national examination?)
   e. Menurut Anda, bab Fisika apa yang dianggap paling susah untuk diterima dan dipahami oleh siswa? (In your opinion, what sub-chapter of Physic is reputed as the most difficult to be accepted and perceivable by student?)

APPENDICES 18

QUESTION FOR AUTODIDACT LEARNING METHO SESSION

1. Medan magnet disekitar penghantar panjang lurus berarus, berbanding terbalik dengan …
   A. Kuat arus listrik
   B. Tegangan listrik
   C. Induktansi diri
   D. Jumlah lilitan kumparan
   E. Jarak titik dari penghantar

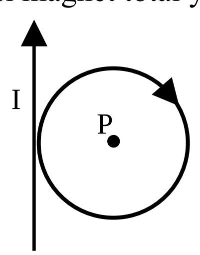
2. Dua kawat a dan b diletakkan sejajar pada jarak 8 cm satu sama lain (gambar di bawah). Tiap kawat dialiri arus sebesar 20 A. Jika $\mu_0/4\pi = 10^{-7}$ Tm/A, maka induksi magnet di titik P yang terletak di antara kedua kawat pada jarak 2 cm dari kawat a dalam mT adalah …



   A. 0,1
   B. 0,13
   C. 0,2
   D. 0,25
   E. 0,3

3. Dua kawat yang sangat panjang dipasang vertical sejajar dengan jarak d. Kawat pertama dialiri arus sebesar I ke atas. Pandang titik P (dalam bidang kedua kawat itu) yang terletak diantaranya dan berjarak 1/3 d dari kawat pertama. Jika induksi magnet di titik P sama dengan nol, berarti arus yang mengalir dalam kawat kedua …
   A. 1/3 I ke bawah
   B. ½ I ke bawah
   C. 3 I ke atas
   D. 2 I keatas
   E. 2 I ke bawah

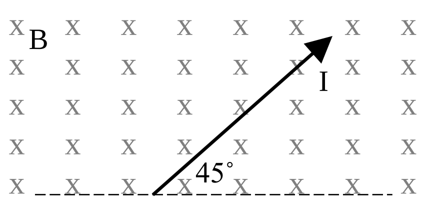
4. Kawat lurus panjang dan kawat melingkar dialiri arus sama besar 4 A. Keduanya didekatkan tanpa bersentuhan seperti gambar. Jari-jari lingkaran 4 cm. Besar induksi magnet total yang timbul di pusat lingkaran (titik P) adalah …



   A. $3{,}14 \cdot 10^{-5}$ tesla
   B. $4{,}14 \cdot 10^{-5}$ tesla
   C. $4{,}28 \cdot 10^{-5}$ tesla
   D. $5{,}28 \cdot 10^{-5}$ tesla
   E. $8{,}28 \cdot 10^{-5}$ tesla

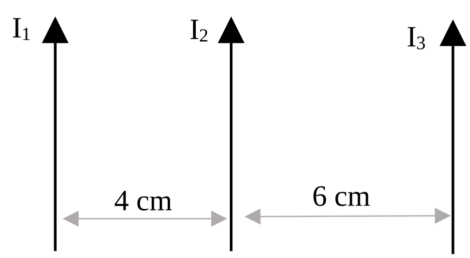
5. Induksi magnetic pada solenoid menjadi bertambah besar, bila …
   A. Jumlah lilitannya diperbanyak, arusnya diperkecil
   B. Jumlah lilitannya dikurangi, arusnya diperbesar
   C. Jumlah lilitan diperbanyak, arus diperbesar
   D. Solenoidanya diperpanjang, arusnya diperbesar
   E. Solenoidanya diperpanjang, arusnya diperkecil

6. Perhatikan gambar berikut ini. Kawat yang panjangnya 50 cm, berarus listrik 2 A diletakkan pada medan magnet B = 5.10^{-4} tesla. Gaya yang bekerja pada kawat adalah …



   A. $2,5 \cdot 10^{-4}$ N
   B. $2,5\sqrt{2} \cdot 10^{-4}$ N
   C. $5 \cdot 10^{-4}$ N
   D. $5\sqrt{2} \cdot 10^{-4}$ N
   E. $5\sqrt{3} \cdot 10^{-4}$ N

7. Bila $I_1 = I_3 = 4A$ dan $I_2 = 3A$, maka besar gaya Lorentz per satuan panjang pada kawat yang berarus I_2 adalah …



   A. $8/3 \times 10^{-5}$ N/m
   B. 10^{-5} N/m
   C. $1/3 \times 10^{-5}$ N/m
   D. 10^{-4} N/m
   E. 2×10^{-4} N/m

8. Sebuah elektron bergerak dengan kecepatan 4×10^5 m/s searah dengan sb. X+ memotong medan magnet 5×10^{-4} Wb m^2 searah sb. Z+. Bila e = $1,6 \times 10^{-19}$C, besar dan arah gaya yang bekerja pada electron adalah …
   A. $3,2 \times 10^{-17}$ N searah sb. Y-
   B. $3,2 \times 10^{-17}$ N searah sb. Y+
   C. 8×10^{-22} N searah sb. Y-
   D. 8×10^{-22} N searah sb. Y+
   E. 2×10^{-28} N searah sb. Y-

9. Sebuah zarah bermuatan listrik bergerak dan masuk ke dalam medan magnet sedemikian rupa sehingga lintasannya berupa lingkaran dengan jari-jari 10 cm. Jika zarah lain bergerak dengan laju 1,2 kali zarah pertama, maka jari-jari lingkarannya

20 cm. Ini berarti bahwa perbandingan antara massa per muatan zarah pertama dengan zarah kedua adalah sebagai berikut …

A. 3 : 5
B. 4 : 5
C. 1 : 2
D. 5 : 6
E. 5 : 4

10. Sebuah muatan uji positif bergerak dekat kawat lurus panjang yang dialiri arus listrik I. Suatu gaya yang mempunyai arah menjauh dari kawat akan terjadi pada muatan uji tersebut apabila arah geraknya …

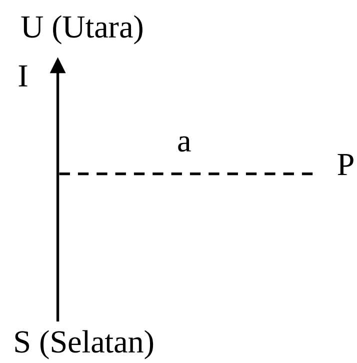
A. Searah dengan arah arus
B. Berlawanan dengan arah arus
C. Mendekati kawat secara tegak lurus
D. Menjauhi kawat secara tegak lurus
E. Tegak lurus baik terhadap arah arus maupun terhadap arah menuju kawat

~ Selesai, Terimakasih ~

APPENDICES 19

QUESTION FOR NON-AUTODIDACT LEARNING METHOD SESSION

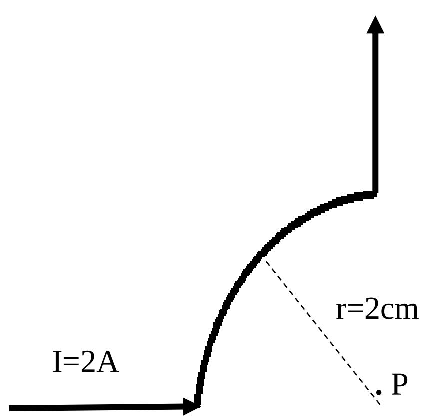
1. Kawat dialiri arus listrik I seperti pada gambar di bawah ini! Pernyataan yang sesuai gambar, Induksi magnetic di titik P akan:
   (1) Sebanding kuat arus I
   (2) Sebanding 1/a
   (3) Tergantung arah arus listrik I

   Pernyataan yang benar adalah…

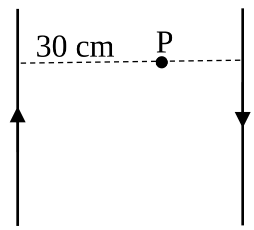
   A. (1), (2), dan (3)
   B. (1) dan (2)
   C. (1) dan (3)
   D. (1) saja
   E. (2) saja

2. Perhatikan gambar kawat yang dialiri arus berikut! Besar induksi magnetic di titik P adalah…
   A. 0,5 π x 10^{-5} $Wb.m^{-2}$
   B. π x 10^{-5} $Wb.m^{-2}$
   C. 1,5 π x 10^{-5} $Wb.m^{-2}$
   D. 2,0 π x 10^{-5} $Wb.m^{-2}$
   E. 3,0 π x 10^{-5} $Wb.m^{-2}$

3. Sebuah solenoid jari-jarinya 2 mm dan panjangnya 50 cm memiliki 400 lilitan. Jika dialiri arus 2 A maka tentukan induksi magnet di titik tengah suatu solenoid!
   A. 3,2 π x 10^{-5} $Wb.m^{-2}$
   B. 5,6 π x 10^{-5} $Wb.m^{-2}$
   C. 6,4 π x 10^{-5} $Wb.m^{-2}$
   D. 7,2 π x 10^{-5} $Wb.m^{-2}$
   E. 2 π x 10^{-5} $Wb.m^{-2}$

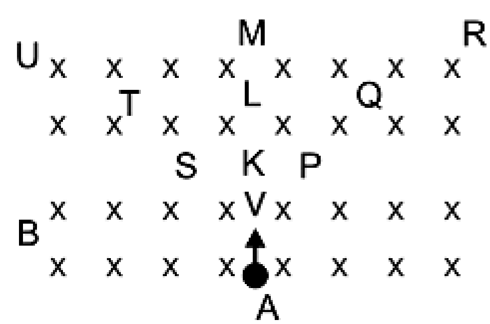
4. Dua kawat sejanar yang sangat panjang dialiri arus listrik yang sama besar yaitu 3A. Jika jarak kedua kawat adalah 40 cm, maka induski magnte di titik P adalah…
   A. 2×10^{-6} T
   B. 4×10^{-6} T
   C. 6×10^{-6} T
   D. 8×10^{-6} T
   E. 12×10^{-6} T



5. Dua buah kawat sejajar yang dilalui arus listrik yag sama besar dan arahnya akan …
   A. Saling tarik menarik
   B. Saling tolak menolak
   C. Tidak saling mempengaruhi
   D. Arus listriknya menjadi nol
   E. Arus listriknya menjadi dua kali lipat

6. Dua titik A dan B berada di sekitar kawat lurus berarus listrik I. Jarak titik tersebut dari kawat masing-masing 6 cm dan 9 cm. Maka besar perbandingan induksi magnetic antara titik A dan titik B adalah…
   A. 1 : 2
   B. 2 : 1
   C. 2 : 3
   D. 3 : 1
   E. 3 : 2

7. Perhatikan gambar dibawah! Dari titik A sebuah electron bergerak dengan kecepatan v memasuki magnet B. Salah satu lintasan yang mungkin dilalui electron adalah …
   A. K – L – M
   B. S – T – U
   C. P – Q – R
   D. P – K – R
   E. S – K – U



8. Dua kawat sejajar l dan m masing-masing panjangnya 2 m dan terpisah pada jarak 2 cm. Pada kawat m yang kuat arusnya 1,5 A mengalami gaya magnetic dari kuat arus pada kawat l sebesar 6×10^{4} N. Kuat arus pada kawat l adalah …

A. 1,2 A
B. 1,5 A
C. 2,0 A
D. 2,4 A
E. 3,0 A

9. Sebuah partikel dengan muatan sebesar 1 µC bergerak membentuk sudut 30º terhadap medan agnet homogeny B=10^{-4} T yang mempengaruhinya. Kecepatan partikel tersebut 2000 m/s, maka gaya Lorentz yang dialaminya adalah …
   A. Nol
   B. 2 x 10^{-6} N
   C. 4 x 10^{-6} N
   D. 10^{-7} N
   E. 10^{-4} N

10. Sebuah penghantar lurus panjang dialiri arus listrik 1,5 A. Sebuah electron bergerak dengan kecepatan 5 x 10^{4} m/s searah dengan arus dalam penghantar, pada jarak 0,1 m dari penghantar itu. Jika muatan electron itu -1,6 x 10^{-19} C, maka besar gaya pada electron oleh arus dalam penghantar itu adalah …
    A. 1,5 x 10^{-20} N
    B. 2,4 x 10^{-20} N
    C. 3,2 x 10^{-19} N
    D. 4,2 x 10^{-19} N
    E. 5,0 x 10^{-19} N

~ Selesai, Terimakasih ~

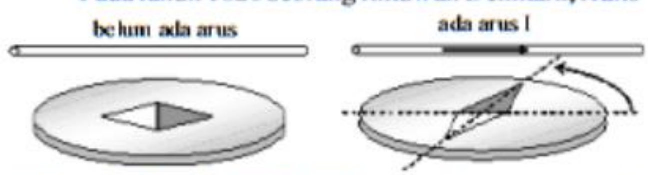
APPENDICES 20

PHYSICS BOOK FOR AUTODIDACT LEARNING TYPE

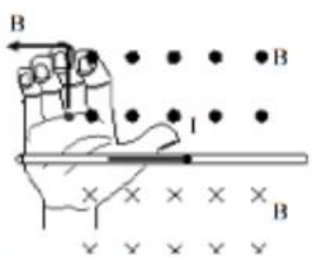
A. Medan Magnet oleh Kawat Berarus

Pada awalnya orang menemukan bahwa logam-logam tertentu dapat dibuat sebagai magnet. Magnet inilah yang dapat menimbulkan medan magnet. Magnet ini ada yang berbentuk batang, jarum dan ladam. Batang magnet ini memiliki dua kutub yaitu kutub utara U dan kutub selatan S. Dua kutub sejenis akan tolak menolak dan kutub tidak sejenis akan tarik menarik.

Pada tahun 1820 seorang ilmuwan Denmark, *Hans Christian Oersted* (1777-1857) menemukan suatu gejala yang menarik. Saat jarum kompas diletakkan di sekitar kawat berarus ternyata jarum kompas menyimpang. Kemudian disimpulkan bahwa di sekitar kawat berarus timbul medan magnet. Medan magnet oleh kawat berarus inilah yang dinamakan induksi magnet.



Gambar 5.1
Pengaruh kawat berarus terhadap kompas



Gambar 5.2
Kaidah tangan kanan. Arah induksi magnet masuk bidang, gambar disimbolkan ⊗ dan keluar bidang, gambar disimbolkan ◉

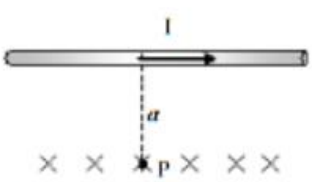
Induksi magnet merupakan besaran vektor arahnya dapat ditentukan dengan menggunakan kaedah tangan kanan. Lihat *Gambar 5.2*. Ibu jari sebagai arah arus I dan empat jari lain sebagai arah induksi magnet B. Sedangkan besaran induksi magnetnya dipengaruhi oleh kuat arusnya I, jarak titik ke penghantar dan bentuk penghantarnya. Perhatikan penjelasan berikut.

1. Kawat Lurus Panjang Berarus

Induksi magnet di sekitar kawat lurus panjang sebanding dengan kuat arus I dan berbanding terbalik dengan jaraknya a. Konstanta pembandingnya adalah $\frac{\mu_0}{2\pi}$. Perhatikan persamaan berikut.

$$B_p = \frac{\mu_0 i}{2\pi a} \quad \text{...} \quad (5.1)$$

dengan : B_p = induksi magnet di titik P (wb/m2)
i = kuat arus listrik (A)
a = jarak titik P ke kawat (m)
μ_0 = permiabilitas hampa ($4\pi.10^{7}$ wb/Am)



Gambar 5.3
Kawat lurus panjang berarus. Di titik P, induksi masuk bidang gambar (X)

CONTOH 5.1

Dua kawat lurus panjang berarus listrik sejajar dengan jarak 15 cm. Kuat arusnya searah dengan besar I_A = 10 A dan I_B = 15 A. Tentukan induksi magnet di suatu titik C yang berada diantara kedua kawat berjarak 5 cm dari kawat I_A.

Penyelesaian

$I_A = 10$ A

$I_B = 15$ A

$a_A = 5$ cm

$a_B = 10$ cm

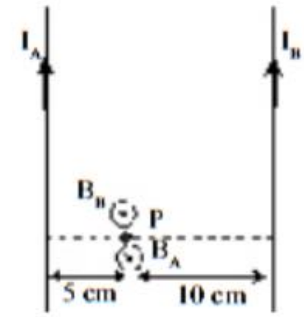
Letak titik C dapat dilihat seperti pada *Gambar 5.4*. Sesuai kaedah tangan kanan arah induksi magnetnya berlawanan arah sehingga memenuhi :

$$B_C = B_A - B_B$$

$$= \frac{\mu_0 I_A}{2\pi a_A} - \frac{\mu_0 I_B}{2\pi a_B}$$

$$= \frac{\mu_0}{2\pi}\left(\frac{I_A}{a_A} - \frac{I_B}{a_B}\right)$$

$$= \frac{4\pi.10^{-7}}{2\pi}\left(\frac{10}{5.10^{-2}} - \frac{15}{10^{-1}}\right) = 10^{-5} \text{ wb/m}^2$$



Gambar 5.4
Induksi magnet di suatu titik oleh dua kawat berarus. B_B keluar bidang dan B_A masuk bidang.

Setelah memahami contoh di atas dapat kalian coba soal berikut.

Dua kawat lurus panjang A dan B berjarak 10 cm satu sama lain. Keduanya dialiri arus sebesar I_A = 2 A dan I_B = 3 A. Tentukan :

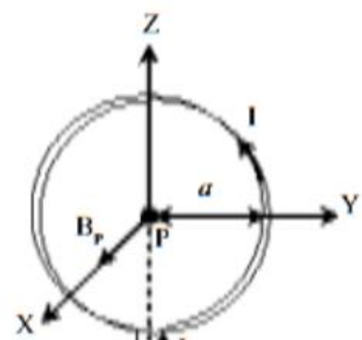
a. Induksi magnet di titik tengah antara kedua kawat,

b. letak titik yang induksi magnetnya nol!

2. Kawat Melingkar Berarus

Perhatikan Gambar 5.5. Sebuah kawat dilingkar-lingkarkan kemudian dialiri arus, jari-jari a dan terdapat N lilitan. Sesuai kaedah tangan kanan, induksi magnet di pusat lingkaran P arahnya ke sumbu X positif. Besarnya induksi magnet sebanding dengan kuat arus I dan berbanding terbalik dengan a. Konstanta pembandingnya $\frac{\mu_0}{2}$.

$$Bp = \frac{\mu_0 i}{2a} N \quad \text{..........} \quad (5.2)$$



Gambar 5.5
Induksi magnet di pusat lingkaran.

CONTOH 5.2

Kawat melingkar terdiri dari 50 lilitan dialiri arus sebesar 5 A. Jari-jari lingkaran 15 cm. Tentukan besar induksi magnet di pusat lingkaran tersebut.

Penyelesaian

I = 5 A

N = 50

a = 15 cm = 15.10^{-2} m

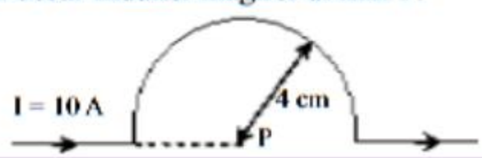
Induksi magnet di pusat lingkaran memenuhi :

$$Bp = \frac{\mu_0 i}{2a} N$$

$$= \frac{4\pi.10^{-7}.5}{2.15.10^{-2}} . 50 = 3{,}3\pi . 10^{-4} \text{ wb/m}^2$$

Setelah memahami contoh di atas dapat kalian coba soal berikut.

Sebuah kawat dibuat setengah lingkaran seperti gambar di bawah. Jika dialiri arus 10 A maka tentukan arah dan besar induksi magnet di titik P.

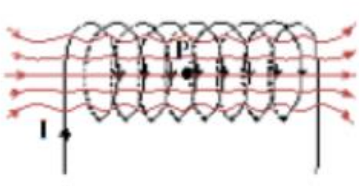


3. Solenoida Berarus

Solenoida adalah nama lain dari kumparan yang dipanjangkan, lihat *Gambar 5.6.* Kuat medan magnet pada titik yang berada di pusat sumbu solenoida memenuhi persamaan berikut.

$$Bp = \mu_0 \, i \, n$$

$$\text{dan} \quad n = \frac{N}{\ell} \quad \text{.................................} \quad (5.3)$$



Gambar 5.6
Solenoida berarus

CONTOH 5.3

Sebuah solenoida jari-jarinya 2 mm dan panjangnya 50 cm memiliki 400 lilitan. Jika dialiri arus 2 A maka tentukan induksi magnet di titik tengah suatu solenoida!

Penyelesaian

ℓ = 50 cm = 0,5 m
N = 400
I = 2 A

Induksi magnet di titik tengah suatu solenoida sebesar :

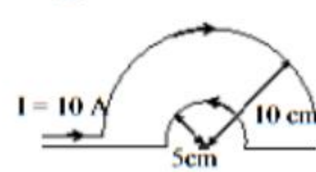
$$B = \mu_0\, i\, n$$
$$= 4\pi.10^{-7}\,.\,2\,.\left(\frac{400}{0,5}\right)$$
$$= 6,4\pi\,.\,10^{-4}\ \text{wb/m}^2$$

Setelah memahami contoh di atas dapat kalian coba soal berikut.
Kuat arus 5 A dialirkan pada solenoida yang memiliki kerapatan lilitan 1000 lilitan/m. Tentukan kuat medan magnet di titik tengah suatu solenoida.

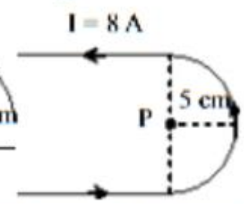
ATIHAN 5.1

1. Kawat lurus panjang berarus listrik 5 A diarahkan mendatar dari selatan ke utara. Tentukan arah dan besar induksi magnet pada titik yang berjarak 4 cm di :
   a. atas kawat,
   b. bawah kawat,
   c. di timur kawat,
   d. di barat kawat.
2. Dua kawat lurus panjang berjarak 8 cm satu dengan yang lain. Kedua kawat dialiri arus I_1 = 5 A dan I_2 = 6 A. Tentukan kuat medan listrik di titik yang berjarak 2 cm dari I_1 dan 6 cm dari I_2.
3. Kawat A berarus 6 A dan kawat B berarus 8 A dipasang sejajar pada jarak 14 cm. Tentukan letak suatu titik yang memiliki kuat medan magnet nol jika :
   a. arusnya searah,
   b. arusnya berlawanan arah!
4. Tentukan induksi magnet di titik P pada kawat-kawat berarus seperti di bawah.

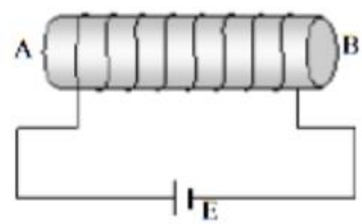
a.



b.



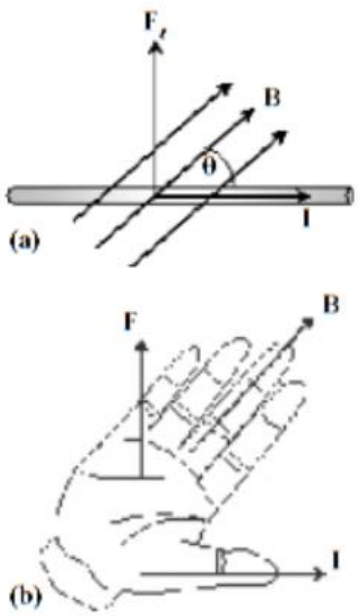
5. Sebuah solenoida dihubungkan dengan sumber arus seperti gambar di bawah. Solenoida itu dapat menjadi magnet. Tentukan kutub-kutub magnet yang terjadi !



6. Suatu solenoid memiliki panjang 1,5 meter dengan 500 lilitan dan jari-jari 5 mm. Bila solenoid itu dialiri arus sebesar 0,2 A, tentukanlah induksi magnet di tengah solenoid ! ($\mu_0 = 4\pi\ 10^{-7}$ Wb / Am)

B. Gaya Lorentz

Sudah tahukah kalian dengan gaya Lorentz ? Di SMP kalian sudah belajar gaya ini. Gaya Lorentz merupakan nama lain dari gaya magnetik yaitu gaya yang ditimbulkan oleh medan magnet. Kapan akan timbul bila ada interaksi dua medan magnet, contohnya adalah kawat berarus dalam medan magnet, kawat sejajar berarus dan muatan yang bergerak dalam medan magnet. Cermati penjelasan berikut.



Gambar 5.7

1. Kawat Berarus dalam Medan Magnet

Pada setiap kawat berarus yang diletakkan dalam daerah bermedan magnet maka kawat tersebut akan merasakan gaya magnet. Gaya magnet atau gaya Lorentz merupakan besaran vektor. Arahnya dapat menggunakan kaedah tangan kanan seperti pada *Gambar 5.7*. Ibu jari sebagai arah I, empat jari lain sebagai arah B dan arah gaya Lorentz sesuai dengan arah telapak.

Besarnya gaya Lorentz sebanding dengan kuat arus I, induksi magnet B dan panjang kawat ℓ. Jika B membentuk sudut θ terhadap I akan memenuhi persamaan berikut.

$$F_\ell = B\, I\, \ell \sin\theta \qquad (5.4)$$

dengan : F_ℓ = gaya Lorentz (N)
B = induksi magnet (wb/m^2)
I = kuat arus listrik (A)
ℓ = panjang kawat (m)
θ = sudut antara B dengan I

CONTOH 5.4

Sebuah kawat yang dialiri arus 3 A berada dalam medan magnet 0,5 tesla yang membentuk sudut 30°. Berapakah besar gaya Lorentz yang dirasakan kawat tersebut sepanjang 5 cm?

Penyelesaian

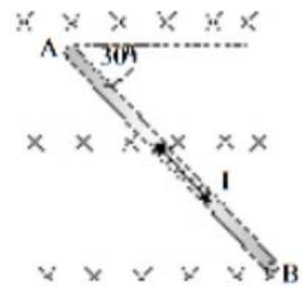
I = 3 A
B = 0,5 tesla (1 tesla = 1 wb/m^2)
θ = 30°
ℓ = 5 cm = 5.10^{-2} m

Gaya Lorentz memenuhi :

$F_\ell = B\, I\, \ell \sin 30^\circ$
$= 0{,}5 \,.\, 3 \,.\, 5.10^{-2} \,.\, \frac{1}{2}$
$= 3{,}75 \,.\, 10^{-2}$ N

Setelah memahami contoh di atas dapat kalian coba soal berikut.

Sebuah kawat berada dalam medan magnet seperti *Gambar 5.8*. Medan magnet homogen 2.10^{-3} wb/m^2 masuk bidang gambar. Jika kawat dialiri arus 6A dan panjang AB = 60 cm maka tentukan besar dan arah gaya Lorentz yang dirasakan kawat AB.



Gambar 5.8

2. Kawat sejajar berarus

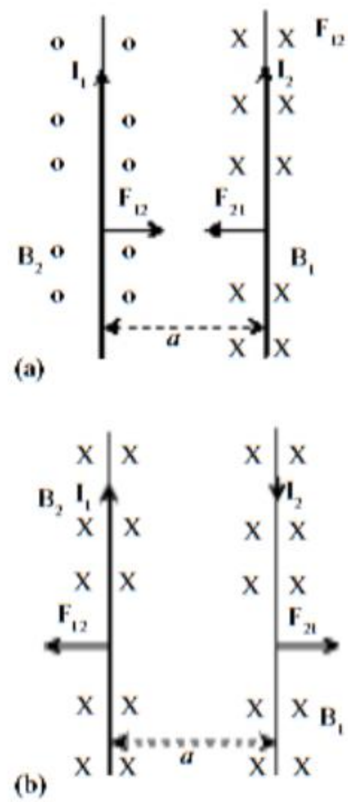
Di sekitar kawat berarus timbul induksi magnet. Apa yang akan terjadi jika kawat berarus lain didekatkan kawat pertama? Keadaan ini berarti ada dua kawat sejajar. Kawat kedua berada dalam induksi magnet kawat pertama, sehingga akan terjadi gaya Lorentz. Begitu juga pada kawat kedua akan menimbulkan gaya Lorentz pada kawat pertama. Gaya itu sama besar dan memenuhi persamaan berikut.

$$F_{21} = i_2 \ell B_1$$

dan $B_1 = \dfrac{\mu_0 i_1}{2\pi a}$

$$F_{21} = F_{12} = i_2 l \left(\frac{\mu_0 i_1}{2\pi a_1}\right) \quad \text{.......................} \quad (5.5)$$

Bagaimanakah arahnya ? Kawat sejajar yang diberi arus searah akan tarik menarik dan diberi arus berlawanan akan tolak menolak. Perhatikan *Gambar 5.9*. Bagaimana hal ini bisa terjadi? Tentukan dengan menggunakan kaedah tangan kanan.



Gambar 5.9
Gaya Lorentz pada kawat sejajar.

CONTOH 5.5

Diketahui dua buah kawat sejajar dialiri arus $I_A = 2$ A dan $I_B = 6$ A dengan arah berlawanan dan berjarak 8 cm. Tentukan gaya Lorentz yang dirasakan oleh kawat I_B sepanjang 20 cm karena pengaruh I_A!

Penyelesaian

$I_A = 2$ A
$I_B = 6$ A
$a = 8$ cm
$l = 20$ cm $= 0{,}2$ m

Gaya Lorentz I_B oleh I_A memenuhi :

$$F_{BA} = i_B \ell B_A$$

$$= i_B\,\ell\left(\frac{\mu_0\, i_A}{2\pi a}\right)$$

$$= 6\,.\,0{,}2\left(\frac{4\pi.10^{-7}.2}{2\pi.8.10^{-2}}\right) = 6.10^{-6}\ \text{N}$$

Arahnya adalah tolat menolak karena arah arusnya sama.

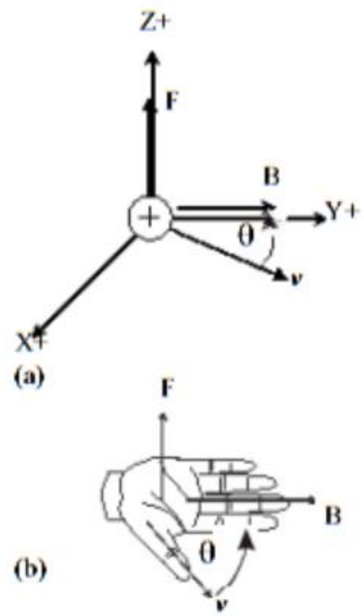
Setelah memahami contoh di atas dapat kalian coba soal berikut.

Dua kawat sejajar lurus panjang berjarak 20 cm satu sama lain. Kedua kawat dialiri arus masing-masing I_1 = 10A dan I_2 = 20 A dengan arah berlawanan. Tentukan arah dan besar gaya Lorentz yang dialami kawat I_2 sepanjang 50 cm!

3. Gaya Lorentz pada Muatan Bergerak

Muatan bergerak dapat disamakan dengan arus listrik. Berarti saat ada muatan bergerak dalam medan magnet juga akan timbul gaya Lorentz. Arus listrik adalah muatan yang bergerak dan muatan yang dimaksud adalah muatan positif.

Gaya Lorentz yang dirasakan muatan positif dapat ditentukan dengan kaedah tangan kanan. Perhatikan *Gambar 5.10*. Ibu jari menunjukKan arah v, 4 jari lain menjadi arah B dan telapak arah gaya Lorentz. Bagaimana dengan muatan negatif ? Coba kalian pikirkan !



Gambar 5.10

(a) Pengaruh gaya Lorentz pada muatan bergerak (b) kaedah tangan kanan.

Gaya Lorentz yang dirasakan oleh muatan bergerak tersebut memenuhi persamaan berikut.

$$F = q\,v\,B\sin\theta \quad \text{.............................} \quad (5.6)$$

dengan : F = gaya Lorentz (N)
q = muatan (C)
v = kecepatan muatan (m/s)
B = induksi magnet (wb/m^2)
θ = sudut antara v dan B

CONTOH 5. 6

Sebuah partikel bermuatan +5 μC bergerak membentuk sudut 30° terhadap medan magnet homogen 0,5 Wb/m^2 dan kecepatan partikel 4.10^5 m/s maka tentukan gaya Lorentz yang bekerja pada partikel!

Penyelesaian

q = +5 μC = 5.10^{-6} C

$v = 4.10^5$ m/s
$\theta = 30^o$
$B = 0,5$ Wb/m²

Besar gaya Lorentz pada muatan itu memenuhi :

$F = q\, v\, B \sin \theta$
$= 5.10^{-6} . 4.10^5 . 0,5 . \sin 30^o = 0,5$ N

Setelah memahami contoh di atas dapat kalian coba soal berikut.

Sebuah elektron (e = - $1,6.10^{-19}$C) bergerak dengan kecepatan 2000 m/s pada arah tegak lurus medan magnet 0,8 tesla. Tentukan gaya Lorentz yang dirasakan elektron tersebut!

Pengaruh Nilai θ

Perhatikan nilai gaya Lorent pada muatan yang bergerak. $F = qvB\sin\theta$. Nilai θ ini memiliki tiga kemungkinan. Perhatikan ketiga kemungkinan tersebut.

(a) *Nilai θ = 0.*
Nilai θ = 0 terjadi jika v sejajar B akibatnya nilai F = 0. Karena tidak dipengaruhi gaya maka muatannya akan bergerak *lurus beraturan (GLB)*.

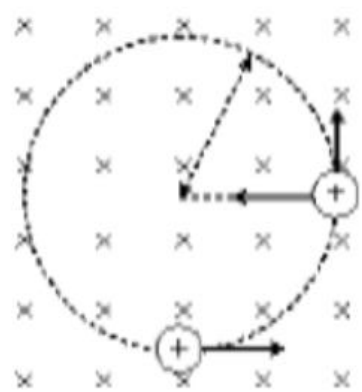
(b) *Nilai θ = 90°.*
Nilai θ = 90° terjadi jika v tegak lurus B. Nilai F = q v B dan selalu tegak lurus dengan v. Keadaan ini menyebabkan akan terjadi *gerak melingkar beraturan (GMB)*. Jari-jarinya memenuhi persamaan berikut. Coba kalian pikirkan dari manakah dapat diperoleh.

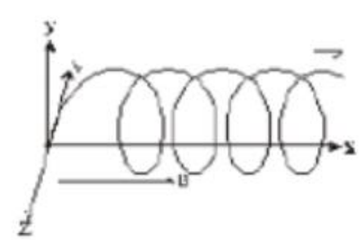
$$R = \frac{m\,v}{B\,q} \quad \text{.. (6.11)}$$

(c) *Nilai 0 < θ < 90°.*
Nilai kemungkinan ketiga ini dapat menyebabkan terjadi perpaduan gerak GLB dan GMB dan terjadi gerak *helix*.

Muatan bergerak di sekitar kawat berarus

Masih ingat induksi magnet ? Kawat yang dialiri arus dapat menimbulkan medan magnet berarti muatan yang bergerak di sekitar kawat berarus sama dengan bergerak dalam medan magnet yaitu akan merasakan gaya Lorentz.Untuk memahaminya dapat kalian perhatikan contoh berikut.


(a)



(b)

Gambar 5.11
(a) Muatan bergerak melingkar dalam medan magnet.
(b) Muatan positif bergerak helix karena pengaruh B searah sumbu X

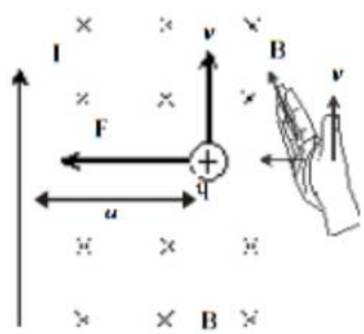
CONTOH 5.7

Sebuah kawat lurus panjang dialiri arus listrik 2 A. Jika terdapat sebuah proton bergerak dengan kecepatan 4 x 10^4 m/s searah arus dalam kawat pada jarak 2 cm dan muatan proton $1,6.10^{-19}$ C, maka tentukan besar dan arah gaya Lorentz pada proton tersebut!

Penyelesaian

$i = 2$ A
$v = 4.10^4$ m/s
$q = 1,6.10^{-19}$ C
$a = 2$ cm $= 0,02$ m

Arah gaya Lorentz dapat menggunakan kaedah tangan kanan dan hasilnya seperti pada *Gambar 5.12.*



Gambar 5.12

Besar gaya Lorentz memenuhi :

$$F = q\,v\,B$$

$$= q\,v\left(\frac{\mu_0\, i}{2\pi\, a}\right)$$

$$= 1,6.10^{-19} \,.\, 4.10^4 \left(\frac{4\pi.10^{-7}.2}{2\pi.0,02}\right)$$

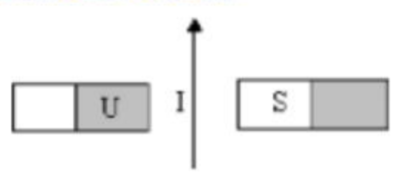
$$= 1,28.10^{-19} \text{ N (mendekati kawat)}$$

Setelah memahami contoh di atas dapat kalian coba soal berikut.

Sebuah penghantar lurus panjang dialiri arus listrik 4 A. Sebuah elektron bergerak dengan kecepatan 2 x 10^4 m/s berlawanan arah arus dalam penghantar dengan jarak 0,05 m dari penghantar itu. Jika muatan elektron $-1,6.10^{-19}$ C, maka tentukan besar dan arah gaya Lorentz pada elektron tersebut!

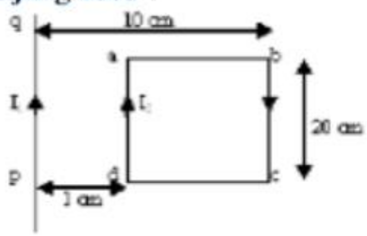
ATIHAN 5.2

1. Arus listrik sebesar 4 A mengalir melalui kawat penghantar. Kawat tersebut tegak lurus suatu medan magnetik 1,2 Wb/m^2. Berapakah gaya Lorentz yang dirasakan pada kawat sepanjang 20 cm !
2. Diantara dua buah kutub magnet U dan S ditempatkan sebuah kawat berarus listrik I. Kawat tersebut akan mendapat gaya Lorentz, tentukan arah gaya Lorentz tersebut!



3. Pada dua buah kawat sejajar yang masing-masing dialiri arus listrik yang sama besar, timbul gaya yang besarnya 2.10^{-7} N/m. Jarak antara kedua kawat itu 1 meter. Berapakah besar arus dalam setiap kawat tersebut ?

4. Pada gambar di bawah terlukis bahwa kawat panjang lurus pq dilalui arus listrik sebesar I_1 = 10 A dan kawat empat persegi panjang abcd dilalui arus I_2 = 5 A. Berapakah resultan gaya yang dialami kawat empat persegi panjang abcd ?



5. Sebuah elektron bergerak dengan kecepatan 2 x 10^5 ms^{-1} searah sumbu Y+ memotong medan magnet 0,8 mWb/m^2 yang searah sumbu X+. Jika e = 1,6 x 10^{-19} C, maka tentukan besar dan arah gaya yang bekerja pada electron tersebut !

6. Suatu partikel alpha (m = $6,4.10^{-27}$ kg dan q = $3,2.10^{-19}$ C) bergerak tegak lurus terhadap medan magnet B yang arahnya masuk bidang gambar. Jika B = 0,5 T dan kecepatan partikel 4. 10^3 m/s, maka tentukan jari-jari lintasannya !

7. Sebuah partikel bermuatan + 8 μC bergerak sejajar dengan kawat berarus listrik 10 A. Jika jarak partikel ke kawat 5 cm dan laju pertikel 5 m/s searah arusnya, maka tentukan besar dan arah gaya yang dialami partikel !

Rangkuman Bab 5

1. Di sekitar kawat berarus timbul induksi magnet. Arahnya sesuai kaedah tangan kanan.
   Besarnya memenuhi :
   a. Di sekitar kawat lurus panjang $B = \frac{\mu_0 I}{2\pi a}$
   b. Di pusat lingkaran : $B = \frac{\mu_0 I}{2a}$
   c. Di tengah sumbu solenoida : $B = \mu_0 I n$
2. Gaya Lorentz adalah gaya yang timbul akibat medan magnet.
   a. Pada kawat berarus dalam medan magnet.
      $F = B\, i\, \ell \sin\theta$
   b. Pada kawat sejajar berarus
      $F = \frac{\mu_0 I_1 I_2}{2\pi a}\, \ell$
   c. Muatan yang bergerak dalam medan magnet.
      $F = B\, q\, v \sin\theta$