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.

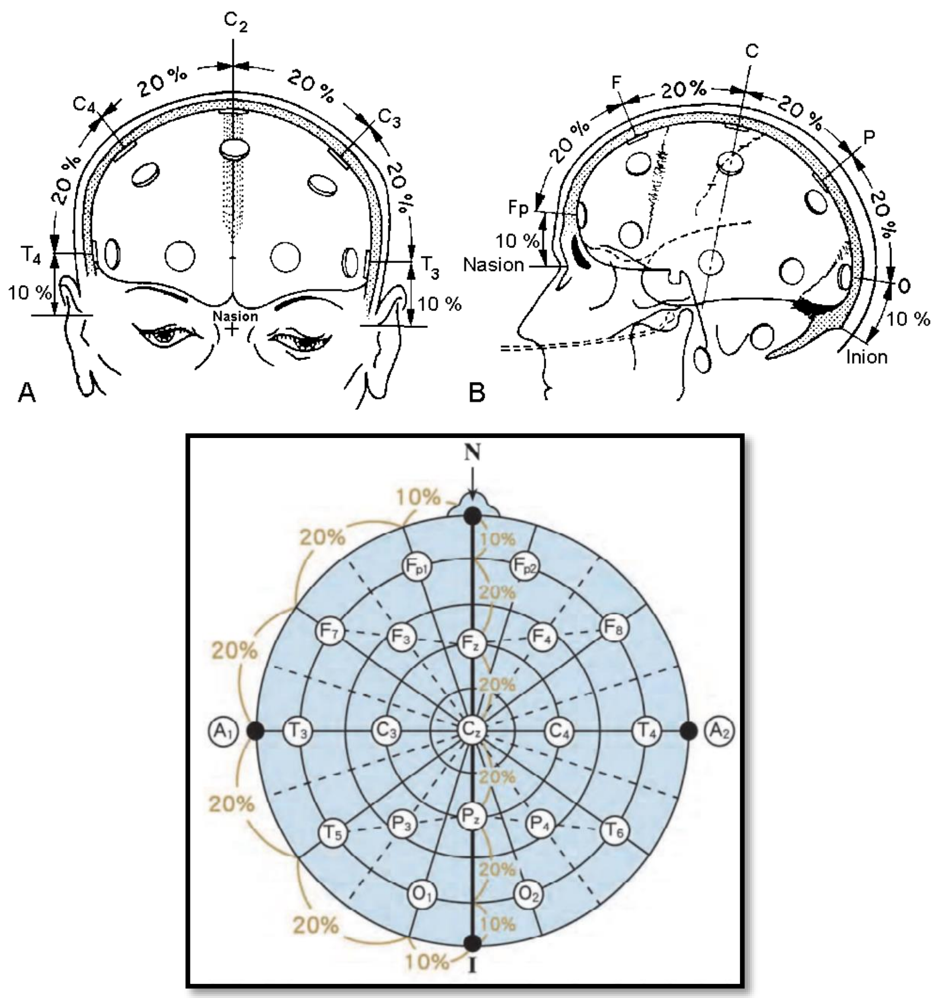

Figure 2.1 International 10-20 System, Electrode Position
(Source: Cheng & Hsu, 2011)

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.

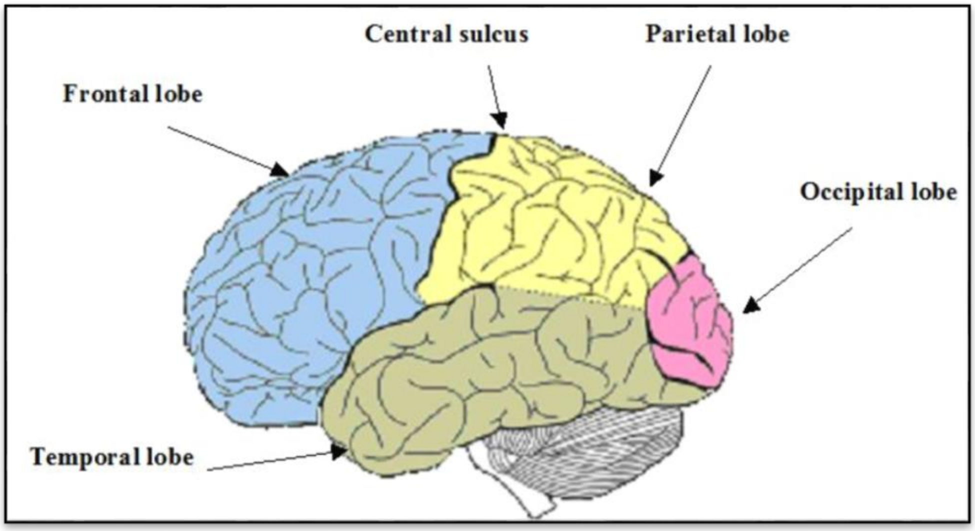

Figure 2.2 The Cerebral Cortex
(Source: Cheng & Hsu, 2011)

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).