The Effects of Emotional Stress on Learning and Memory Cognitive Functions: An EEG Review Study in Education

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***Abstract*— The human body reacts to stress-causing threats by producing hormones for major physiological changes. The body of a stressed student is subject to three major drawbacks including reduced sleep quality, worst grades, and angrier students. On the other hand, Electroencephalography (EEG) is a test for detecting the electrical activity of the brain using electrodes attached to the scalp. EEG recording shows the electrical impulses of the brain, which are used in communication between cells, and they are always active even while sleeping. EEG is useful in diagnosing brain disorders including epilepsy. Based on that, this work, we review the literature on the effects of emotional stress on learning and memory cognitive functions in education based on EEG. For each related work, we indicate the targeted brain region, the used methodology, the effect of the stress on the learning process and interesting highlights. Finally, we highlight the main related challenges and possible future work to address such issues.**

Keywords*— Stress, Learning, Cognitive Functions, Electroencephalography (EEG)

I. INTRODUCTION

Stress can be defined as the response of the human body to any threat or demand [1]. A stressful situation excites a sequence of stress hormones to properly orchestrate physiological changes, which increase a set of body reactions [2]. This set of body reactions for a stressful situation is known as *fight-or-flight*, where the nervous system releases stress hormones, e.g., cortisol and adrenaline, which awaken the body for exigency action [3]. Accordingly, the human body undergoes a set of changes such as raised pulse, faster breathing, sharper sensing, and higher blood pressure, as shown in Fig.1. These changes increase the stamina and strength of the body, with shorter reaction time and enhanced ability to focus [4]. Finally, the person will fight or escape from the stress-causing danger.

Recently, with at-home studying due to the COVID-19 pandemic, students are amenable to various forms of stress due to academic demands in addition to the necessity of staying safe with a minimal secured financial fund in this pandemic [5]. These results in three main effects related to a reduced sleep quality, worst grades, and angrier students. On the other hand, long-term results include reduced academic performance and learning capacity. Moreover, students could suffer mental problems including sleep disturbance, anxiety, and depression. The previously mentioned problems are serious and they should be treated properly [6].

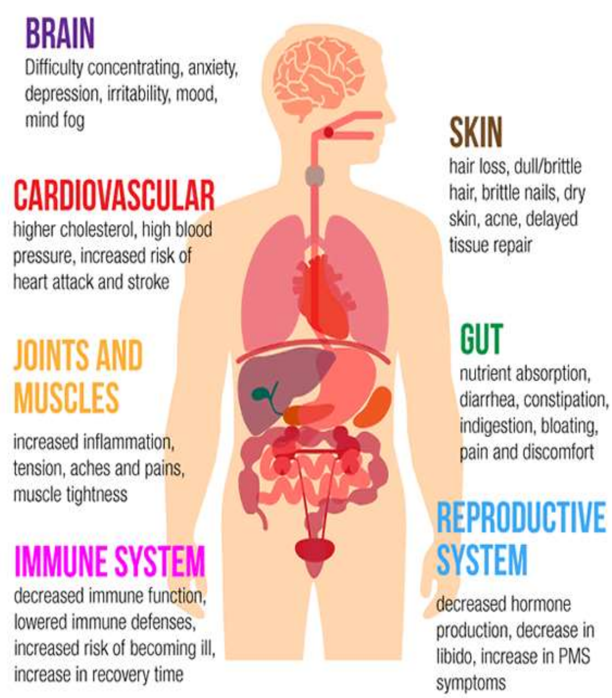

Fig.1. Effects of Mental Stress on the Human Body

Cognitive function is the ability of human's brain to manipulate information about the world, it includes thinking, learning, recall, memory, problem solving and mental flexibility [7], as shown in Fig. 2. Moreover, cognitive function is determined by the neuronal network interactions. Hormones are the chemical governors of the human body , they perform highly to preserve different operations such as cognition, emotion, and growth [8]. Various types of hormones have different effects on the human mind and body. Recently, various studies have showed that hormonal

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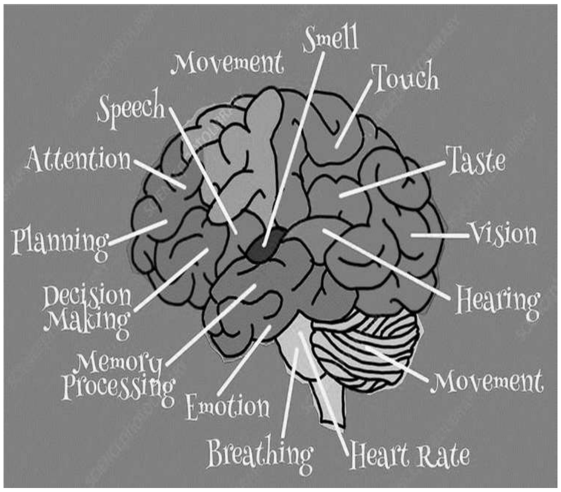

Fig. 2. Major Domains of Cognitive Function

fluctuations lead to defects in cognitive function, for example, Cortisol is a stress hormone, whose levels may fluctuate with certain triggers such as stress. Moreover, the authors of [9], declared that adulthood depressive disorder, which is associated with altered brain structure and brain functions, increases due to childhood early life stress.

Generally, the impacts of emotional stress on memory and learning cognitive functions are not always proved, that is to mean, they could work as facilitating or destroying factors [10]. Stress can facilitate memory and learning processes if it is experienced in directly with the situation and around the time of the event [11]. As an example of wearable sensors, Electroencephalography (EEG) [12, 13] is recently used in various research related to neural engineering, neuroscience, and biomedical engineering [14, 15]. EEG has a high temporal resolution, non-invasiveness, and relatively low financial cost [16]. Here, the proposed research study aims to review the literature of the effects of emotional stress on learning and memory cognitive functions in education based on EEG. Morover, we will discuss the main challenges and few possible future trends.

II. Related Works

Various studies investigated the possibility of utilizing the EEG signals to differentiate stress from the rest state in mental arithmetic tasks [17, 18]. It is well-known that, the EEG power spectrum is subdivided into bandwidths known as *delta* (0.5-4 Hz), *theta* (4-8 Hz), *alpha* (8- 12 Hz), *beta* (12-30 Hz), and *gamma* (above 30 Hz) [19]. Stress could be detected based on the power of theta, alpha and beta bands[20].

Table 1 summarizes various literature works related to the effects of emotional stress on learning and memory cognitive functions in education based on EEG. For each related work, we indcate the targetd brain region, the used methodolgy, the effect of the stress for the learning process and an interesting highlights for ecah related work. Clearly, we notice the disruptive effect for the stress on mental ability including, learning, memory retrievial and attention, and decision making.

Table 1: The Literature Of Effects of Emotional Stress on Learning and Memory Cognitive Functions in Education Based on EEG.

Reference	***Brain region***	***Method***	***Effect***	***Highlight***
[21]	Prefrontal cortex	Canonical correlation analysis (CCA)	Stress disrupts learning and memory	Alpha wave in prefrontal cortex is corrleated with stress and negative situation
[22]	Prefrontal cortex	Joint spare canonical correlation (JSCCA)	Stress disrupts academic performance of students	Brain activities (alpha, beta, and theta) are decreased under stress
[23]	Frontal lobe	EEG, Physiological, and subjective measurements	Stress disrupts working memory	Theta wave in frontal lobe decreases under stress
[24]	Frontal lobe	Statistical analysis	Stress disrupts negatively performance and learning	Alpha and beta in frontal lobe corrleated with stress and negative experiences
[25]	Frontal lobe	Mean power spectrum	Pre- learning stress impaires retrieval stage of long term memory	Pre- learning stress leads to increase the power of theta rhythm espicially at frontal lobe
[26]	Frontal lobe	Cue-Locked analysis	Stress, anxiety, and worry disrupt negatively cognetive functions	Increasing in hemodynamic brain activity in the frontal lobe is occurred
[27]	Frontal and temporal lobes	Regression and neural network	Music stimuli can impair stress level	Relaxed emotions are highlighted
[28]	Frontal lobe	Supervised learning algorithm	Stress disrupts dicision making and memory	EEG rhythms for 14 different channels are analyzed
[29]	Prefrontal cortex	Visual analogue scales (VAS)	Theta/beta ratio reflects attentional control	Alpha and beta waves in prefrontal cortex are associated with attention
[30]	All	Univariate analysis	Alpha and theta power increase	Beta coherence increases under stress
[31]	Frontal and temporal lobes	Wavelet transform	Stress disrupts negatively cognetive functions	Emotion assessment based on EEG and psychophysiological signals is proposed
[32]	Frontal and parietal lobes	Behavioral and brain dynamics analysis and	Stress disrupts negatively working memory and attention	Theta, alpha, and gamma bands are associated with stressful conditions
[33]	Temporal lobe	Mean power spectrum	Pre- learning stress impaires retrieval stage of long term memory	Main power of theta band increses at the temporal lobe for pre-learning stressor
[34]	Frontal lobe	Genetic algorithm	Stress disrupts negatively cognetive functions	The power of the alpha band changes slightly during stressful conditions

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Reference	*Brain region*	*Method*	*Effect*	*Highlight*
[35]	Prefrontal cortex	Statistical analysis	Alpha band is associated with teaching and learning	The power of the alpha band increases at Prefrontal during stressful conditions
[36]	Frontal lobe	Neuroanatomical, time domain, frequency domain analysis	Alpha band is associated with learning	The power of the alpha band changes during stressful conditions
[37]	All	Statistical analysis	Alpha, beta, and theta waves are associated with cognetive functions	Theta band is associated with stressful exam
[38]	All	Hilbert-Huang transform and support vector machine	Stress disrupts negatively learning and academic performance	The power of the alpha band increases during stressful exam
[39]	All	Deep learning neural networks	Different levels of stress are classiffied	Stress recognition framework based on EEG is presented
[40]	Frontal lobe	Univariate analyses of variance	Alpha band is associated with memory and attention	stress leads to impair thinking, memory, and learning
[41]	ALL	Independent component analysis and SVM	Stress is associated with attention and focusing	Relaxed emotions are highlighted
[42]	Frontal, parietal, and central lobes	Spectral powers analysis	Resting and relaxing lead to enhance attention, memory, and learning	Alpha and theta powers are increasing during resting state
[43]	Frontal lobe	Dominant and opponent processes	Frontal lobe is associated with emotional states, performance, learning, and motivation	Increasing of alpha activity indicates attention, learning, and memory cognitive functions
[17]	ALL	SVM, statistical features, fractal dimension	Stress and anxiety disrupt negatively cognetive functions	Alpha, beta, and theta are are associated with stressed and relaxed states
[44]	Frontal lobe	Spectral powers analysis	Frontal lobe is associated with performance, learning, attention	Alpha, beta, and theta power decreased in stress state
[45]	Frontal lobe	Statistical analysis	Right hemispheric activation is asociated with stress and poor performance	Alpha asymmetry is asociated with attention and performance
[46]	Frontal, centeral, and parietal lobes	Fourier transform and statistical analysis	Theta/beta power ratio is asociated with anxiety and stress	Theta and beta power is increased in parietal lobe under anxiety and stress
[47]	Prefrontal cortex	Digit span and statistical analysis	Stress impairs working memory	Alpha is associated with focusing, attention, and performance
[48]	ALL	Functional connectivity and Fourier transform	Stress disrupts negatively motor and cognitive functions	The power and functional connectivity increase under stress
[49]	Occipital and parietal lobes	Relative power	Stress disrupts negatively memory retrieval and attention	Theta and alpha power are increased in parietal and occipital lobe under stress
[50]	Occipital and centeral lobes	Coherence and spectral powers analysis	Stress disrupts memory retrieval	No changes occure in power for all bands
[51]	Frontal, temporal, and parietal lobes	Support vector machine	Frontal, temporal, and parietal lobes are associated with emotional states, performance, and learning	Alpha and beta are asociated with attention and performance

III. RESULTS AND DISCUSSION

The brains of all mammals, including humans, contain four lobes in the cortex, including the occipital, parietal, temporal, and frontal lobes. Next, we explain each lobe and its major responsibilities.

The occipital lobe is the part of the human brain which is responsible for interpreting information from the eyes and turning it into the world as a person sees it. The occipital lobe is the smallest of the lobes, and it is named because it rests below the occipital bone of the skull. The parietal lobe is one of the major lobes in the brain, roughly located at the upper back area in the skull. It processes sensory information it receives from the outside world, mainly relating to touch, taste, and temperature. The temporal lobe is one of the four major lobes of the cerebral cortex, where it is sitting close to ear level within the skull, i.e., the lower lobe of the cortex. It is responsible for creating and preserving both conscious and long-term memory. Moreover, it plays a role in visual and sound processing which is critical for both object recognition and language recognition. The frontal lobe is at the front of the brain, where the left hemisphere of the frontal lobe controls the right part of the body, and vice versa. The frontal lobe is controls important cognitive skills in humans, including memory, emotional expression, language, problem solving, judgment, and sexual behaviors. Thus, it controls our personality and our ability to communicate. The prefrontal cortex (PFC) is an area of the frontal lobe which is located above the eyebrows. The PFC simplifies our decision making where it allows us to expect and imagine possible implications for our behaviors.

Based on the summarized work, listed in Table 1, we notice that all the brain lobes are targeted by researchers. Accordingly, the five bandwidths of the EEG power spectrum are utilized based on the targeted lobes. Moreover, various machine learning algorithms are used in processing the associated EEG signals. Thus, the research on EEG signals still in its infant stages with more opportunities as shown in the next section.

IV. CHALLENGES AND FUTURE TRENDS

Based on the reviewed work, we clearly notice that there are various challenges need to be solved, which represent possible future works. The main challenges include the following:

- Investigating the effects of emotions on knowledge acquiring regarding psychological and physiological changes that accompanying learning process [52].

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- Highlighting gender sensitivity between male and female of controlling the associated stress on neurobiological level [53, 54].
- Investigating whether stress has effects or impacts on the brain development that oblige the brain to change its way of memorizing and learning [55].
- Identifying the effect of self-compassion or self-satisfactory on managing the stress level while acquiring new knowledge [56].
- Considering learner life style and mental health due to their influence in the level of stress among learners [57].

Currently, most studies and research focused on homogeneous group, self-reported samples, and one data resource. Therefore, the future research should vary between these factors such as : heterogeneous group, monitoring or observing report and additional data sources e.g. parents and teachers [58]. Moreover, future research need to explore the direct and indirect factors such as satisfactory, learning experiences, academic goals and achievements, that have effects on the motivation and process of online education [58].

We notice that, students' creativity and self-confidence have a role in students' achievement and motivation. As a result these factors may reduce students stress and anxiety [59]. Exam stress or anxiety of learners is studied in term of age, success, and gender, but the consequences of stress and anxiety and the level of stress caused by these factors should be taken in consideration [60-62].

V. Conlusion

Currently, due to the COVID-19 pandemic, e-learning for all studying stages is a trend. This causes continuous stress and high pressure on students, which will negatively affect their cognitive functions. In this paper, we reviewed a wide range of works that put the light on the effect of emotional stress on student's learning memory and cognitive functions. Therefore, the EEG is utilized by recording the electrical activities of the brain from various regions, e.g., frontal, temporal, occipital, central, and parietal lobes. Finally, we highlighted a few possible research directions based on the current challenges.

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