Exploring students' emotional state during a test-related task using wearable electroencephalogram

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ABSTRACT

Using wireless sensors for brain activity, brain signals associated with the mood states of engineering students have been captured before and during the taking of a mathematics exam. The characterization of brain lobule activity related to arousal/valence states was analyzed from reports on the literature of the horizontal dimensions of pleasure-displeasure and vertical dimensions representing arousal-sleep. The results showed a direct relationship of the level of students' arousal with the event of taking an exam as well as feelings of negative emotions during the exam presentation. The development of this research can lead to the implementation of controlled spaces for the presentation of students' exams in which arousal/valence states can be controlled so that they do not affect their performance and the fulfillment of the goals, achievements or objectives established in a program or subject.

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1. INTRODUCTION

When we study learning in human beings, it is very important to consider the processes that develop in the brain, since this organ is responsible for generating the functions necessary to learn; in many educational systems, learning is measured through academic performance. The learning development processes are usually carried out by means of a constant adaptation to the environment, associated with the phenomenon of neuroplasticity [1], understood as a regeneration/reorganization process during the learning process [2]. To evaluate the development of the objectives established in an academic program, the "academic achievement" is usually used, which is a highly complex process, since it depends on both internal and external variables to the student; for example: cognitive variables, behavioral variables, family environment, social context, emotional state, among others. Recently, some researchers have addressed the relationship between emotions and learning in academic settings, for a better understanding of these aspects see [3]–[6]. This recent exploration of these relationships has been possible due to the access to measurement devices that allow the analysis of emotions from varied data that can include electroencephalographic (EEG) signals in non-medical environments.

Until a few years ago, intelligent tutoring systems (ITS) normally evaluated student knowledge to make decisions as to what type of learning environment is developed for teaching; however, their emotions or moods were not considered in this process. This trend has changed in recent years, since ITS have even evolved to measure brain EEG signals and identify activation zones of the cerebral cortex [7], [8], obtaining greater reliability in the automatic recognition of emotions. In 2015, there were a few consumers grade EEG (electroencephalography) measuring sensors on the market, as a research tool [9], [10]. By 2020, a diverse range of wireless sensors for brain activity devices could be acquired in the online market with which brain signals can be acquired with different objectives in non-medical environments such as cognition, brain–computer interface (BCI), education, and gaming [11], [12].

In the field of education, most of the research carried out focuses on the study of attention. However, no studies have been reported that allow analyzing the mood of students during a specific learning task, such as performing an exam, or if these tasks induced moods that can affect performance on them. Some BCI manufacturers validate performance metrics such as stress/frustration, engagement, interest/valence, excitement, focus/attention, and relaxation/meditation as a measure on their devices from the use of their own software, which can be interesting as application for studying the mood of students during regular academic processes.

Through low-cost EEG devices, studies have been reported in the educational area in which students have been monitored in different aspects while they are doing the learning-related tasks. Sun [13] established that the level of attention of students in reading spaces on mobile devices was lower than in traditional reading. In an experiment on the effect of the displayed text on the user's attention, it has been shown that the different forms of text visualization do not show any important results in the user's attention [14].

According to Ma and Wei [15], there is a difference between the advantages of using audiobooks or e-books in relation to the gender of the student, male or female. Some studies refer to the level of attention of the student, they carry out an analysis with EEG devices [14], [16]–[18]. In the field of affective computing, EEG signals have been used to identify emotions, more recently the possibility of accurately measuring activation and valence [19] corresponding to excitement-relaxation emotions (vertical dimension) and pleasure-displeasure (horizontal dimension) respectively, agreeing to the model proposed by Russell [20]. In this sense, this research proposes the use of a wearable EEG device that allows analyzing the moods of students according to the activation of different areas of the brain as shown in Figure 1 and determining whether these emotions or moods, can affect student performance on tasks related to school environments, such as taking a test.

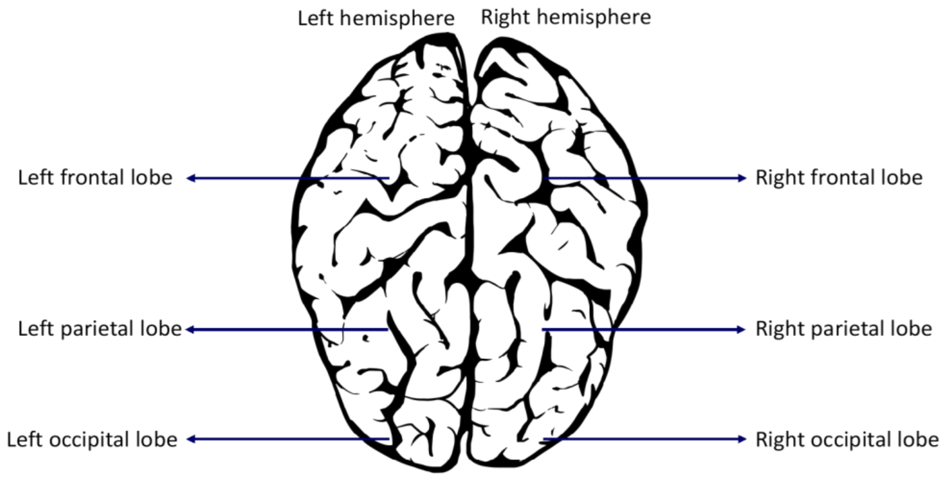

Figure 1. Different areas of the brain to be analyzed

2. THEORETICAL FRAMEWORK

The cognitive approach to learning emphasizes that the behavior of the individual who learns is related to some complex and dynamic mental operations, according to internal mechanisms of representation of knowledge and the world that surrounds us [20]. One of the problems that arise when trying to understand individual differences in the development of learning is precisely the fact that they are due to different neuro-cognitive processes that are not given to the teacher, therefore they cannot be found in the analysis of the different learning environments. One of these traits found in this type of latent variable that influence the development of learning refers to how the attitudes, motivations, and emotions associated with the learning process significantly affect the efficiency and development of this process. In particular, the student's emotion is an important expression of the attitude towards learning, therefore, it is very useful to identify the types of emotions, positive or negative that are presented in students during the learning process, or in some associated activities [19], [21]–[24].

Understanding the role that emotions play in the student's cognitive development, during a learning task, is essential to guide better learning processes, because identifying the aspects of emotions that have a positive or negative impact on learning would be helpful to select new or improved learning strategies [25]–[27]. One of the aspects that positively influence learning is the regulation of emotions [28], [29], essential for the development of learning tasks. From the conceptualization of metacognitive processes according to Flavell [28], it is revealed that when students perform cognitive tasks, they relate their ability to perform the task with their own cognitive resources.

From the reflection that the student performs, it can generate different emotional states, depending on the demand of the task, for example, if it is an exam, the belief that was not enough time studied, or that oneself is not too good to pass the exam raises a state of worry and sometimes anxiety or fear. On the other hand, some research reports maintain that the judgments made by students about their learning processes, positively influence the development of the tasks associated with these processes [30]–[32], in the sense that feelings about knowledge of a task or of knowing the answer to a problem, generate confidence in the student, which assumes that they are capable of performing well in learning tasks [33]–[35].

3. RESEARCH METHOD

From the methodology proposed by Hwang *et al*. [36]–[38] and through the use of a wearable EEG device, images of the activation of the different areas of the brain have been collected during the performing of a mathematics test, carried out by four engineering undergraduates. The valence-arousal model, currently validated, allows the categorization of emotional states [39]. Figure 2 shows the valence-arousal model the horizontal dimension represents pleasure-displeasure while the vertical dimension represents arousal-sleep.

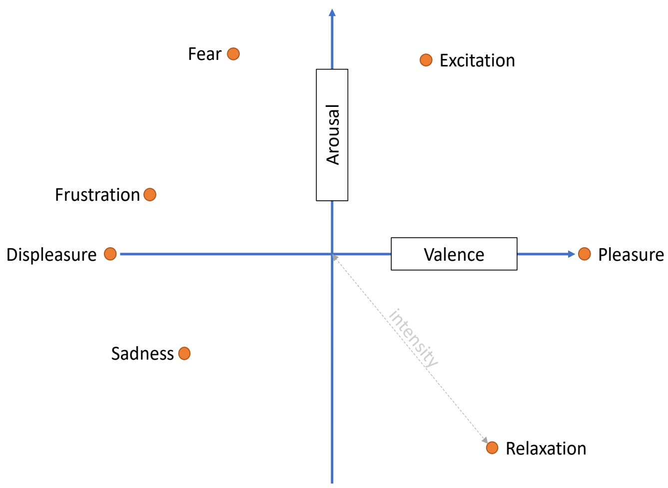

Figure 2. Valence-arousal model adapted from [20], [36]

Arousal is characterized by high potency and beta coherence in the parietal lobe, as well as alpha activity. Beta waves are associated with an alert or excited state of mind, while alpha waves are more dominant in a relaxed state. Thus, the beta/alpha ratio is a reasonable indicator of a person's state of arousal. While in the valence, the prefrontal lobe plays a crucial role in the regulation of emotions and conscious experience. The inactivation of the left frontal indicates a negative emotion, and even the inactivation of the right frontal indicates a positive emotion [38].

The EEG signals were recorded with the OpenBCI device [40], [41], a low-cost open-source bio-signal amplifier that allows the acquisition of brain signals. From electrodes distributed in the upper part of the skull of the students, the signals are registered in time and the activation images of the brain areas will later be associated with the emotions of the student during performing a test as shown in Figure 3. Figure 4 illustrates the real-time functioning of the software registering the signals through a Bluetooth module. The record allows identifying the signals of each of the electrodes in time, the frequency representation of each of the signals employing the fast Fourier transform algorithm, and the view of the upper brain with the analysis of the activation zones (red) and inactivation (blue) corresponding to the status of the student.

Figure 3. Set up of the experiment with one of the students

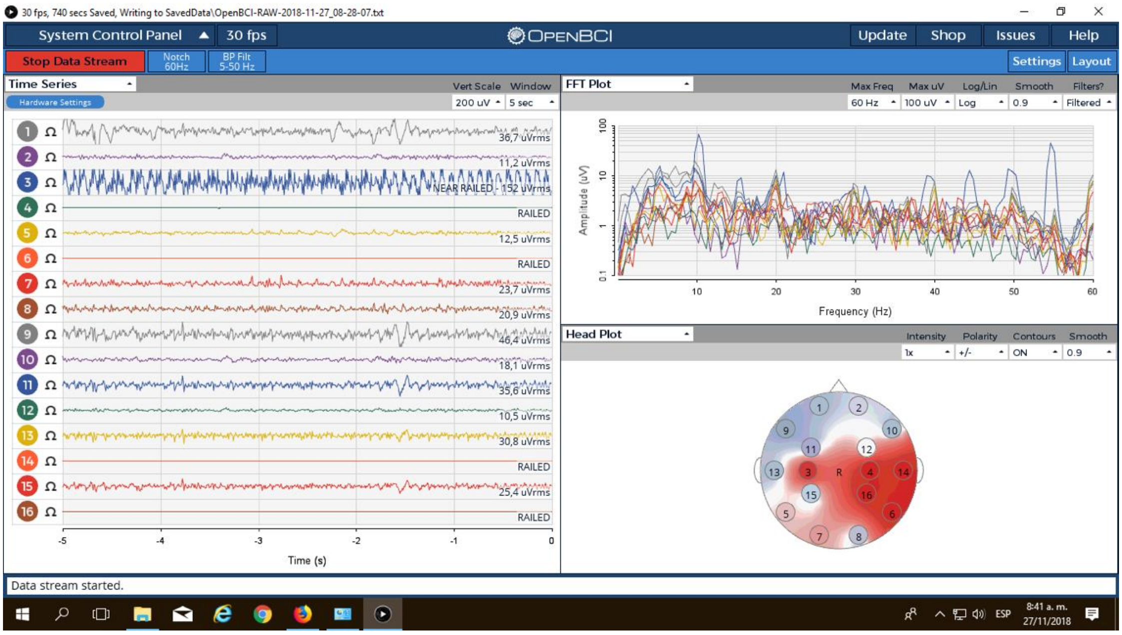

Figure 4. Record of signals and verification of brain activation zones

4. RESULTS AND DISCUSSION

Determining the activation zones of the brain is done by recording the brain signals for each of the students involved in the study in two sessions, the first one is recorded before the test activity and the second one during the test. For the assembly of the test, any type of distractions has been eliminated to avoid cerebral stimuli that could affect the measurements such as noise or movements. Students have been asked to remain as focused as possible on the development of the test that involves a numerical grade for an academic component of mathematics in a program of undergraduate engineering as shown in Figure 5.

Figure 5 shows analyzing each of the students, we can summarize the following results: for student 1, before performing the test as shown in Figure 5 (a), a state of arousal characterized by activation of the parietal lobe and a predominant state of positive emotions due to the activation of the left frontal lobe. During the test as shown in Figure 5(b), student 1 remains in a state of alert or arousal, as for the analysis of valence, the student during the development of the test, clearly shows the lack of activity of the left frontal lobe, which is related to negative emotions.

Student 2, before taking the test as shown in Figure 5(c), shows a state of relaxation according to the lack of activity of his parietal cortex and positive emotions due to the activation of his left frontal lobe, later, during the test, the characteristics presented by Figure 5(d) show a state of arousal with negative emotions with activation of the parietal section and the slight activation of the left frontal lobe. Student 2's signal intensity is reducing (color intensity), this is probably due to his haircut (length of hair).

Students 3 and 4 before taking the test in Figures 5(e) and (g), present a state of arousal with a predominance of positive emotions, later, during the presentation of the test as shown in Figures 5(f) and (h), students have shown a strong predominance of negative emotions; from valence analysis, with activation of the left frontal lobe, and a state of arousal that remains almost unchanged before and during the test.

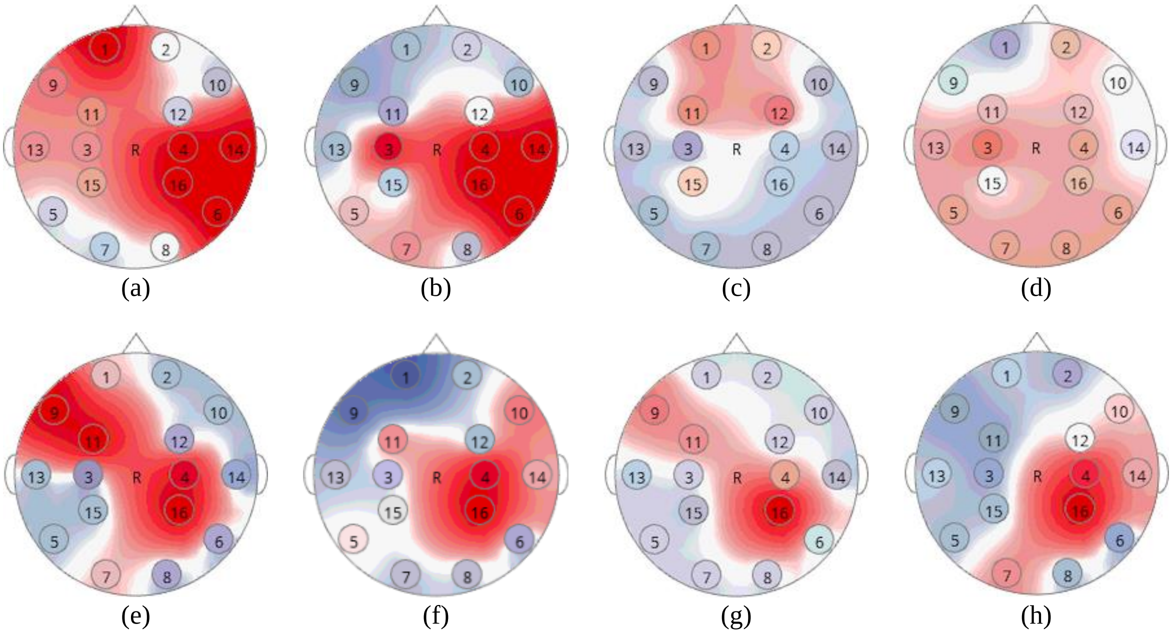

Figure 5. Identification of the brain areas of the students analyzed during the study: (a) student before and (b) during the exam respectively, (c) student 2 before and (d) during the exam respectively, (e) student 3 before and (f) during the exam respectively, (g) student 4 before, and (h) during the exam respectively

5. CONCLUSION

Using a wearable EEG device, the brain activity of the areas related to the emotions of the students has been recorded before and during the completion of an engineering undergraduate mathematics test. The states of arousal/valence have been characterized from literature reports that indicate the activation or deactivation of parietal and frontal lobes and their alpha/beta signals associated with the regulation of emotions and conscious experience. The results show that there is a possible relationship between the emotions registered by the student before and after the test, since the test represents a numerical evaluation for the student. This may affect the students' performance during the exam since the results will depend not only on their cognitive ability and knowledge of the subject but will also be affected by the degree of arousal or control of emotions. Subsequent studies, with a larger sample, can investigate questions such as what kind of actions can be generated to reduce the state of arousal, and furthermore, understanding how to control negative emotions in students when taking a test. These aspects can be explored with the development of controlled environments for tests, stress management and learning about emotion control for students.

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