Measurement of emotional variables through a brain-computer interface in the interaction with books with augmented reality in higher education

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Abstract. This article aims to describe the process of measuring mental state variables through a brain-computer interface in the interaction of humans with books with augmented reality; specifically, it seeks to analyze the variables commitment, stress, interest, relaxation, excitement, concentration in the interaction of students with a book with augmented reality compared with the measurement of the same variables when reading a traditional text. For the process of measuring emotional signals, two texts were designed for the data structure subject of the systems engineering program, the first in traditional format and the second with augmented reality applications. Subsequently, the mental state measures were taken through the brain-computer interface to the sample of students of the subject interacting with the traditional book and the book with augmented reality. Finally, through the interface software application, the results of the variables of each student interacting with the mentioned texts were downloaded and comparatively analyzed. Through comparative analysis, it is shown that the variable of mental state interest increases in the interaction of higher education students with books with augmented reality compared to reading a traditional text. Brain-computer interface systems have become an effective strategy for the measurement of emotional variables in the incorporation of emerging technologies such as augmented reality into teaching-learning processes in higher education.

1. Introduction

Augmented reality (AR) is becoming an emerging technology with great potential for use in the educational sector \cite{1-3}, and in the educational entertainment sector integrating real elements with virtual elements through a computer application \cite{4}. One of the instances of applications of augmented reality in higher education are books with augmented. AR books can be defined as physical books enriched with computer applications that are accessed through images called bookmarks. These books have been used at different levels of education, particularly in higher education, there are scenarios in which this type of resources was used to improve motivation to learn complex concepts, for example Gutierrez et al. \cite{5} designed and implemented an AR book to improve motivation towards learning mechanical concepts in engineering students. However, the process of verifying the improvement of motivation towards learning with the use of AR books in higher education has been difficult, an argument that supports the use of a brain-computer interface to capture emotional variables of the students in the scenario of interacting with AR books. A brain computer interface (BCI) is defined as a communication or control system that...
relies on brain waves (electroencephalogram - EEG) consciously generated to control a real or virtual mechanism [6].

BCIs have evolved over time and in a complementary way you can access these types of devices at reasonable prices, among the models that are on the market are MindFlex by Mattel [7], MindSet by NeuroSky [8], Muse InteraXon [9] and Emotiv Insight. The Emotiv device provides, in addition to the brain signals measured directly from the sensors, six basic measures of mental performance estimated directly from brain activity: engagement, interest, excitement, focus, stress, and relaxation [10]. This work aims to describe the process of measuring mental state variables through a brain-computer interface in the interaction of humans with books with augmented reality.

2. Research methodology

The process of capturing emotional signals through the brain-computer interface is performed by placing the sensors of the Emotiv Insight device in 5 specific positions of the brain to capture the electrical impulses generated depending on the activity that the person is executing, later the system processes these electrical impulses and translates them into the measurement of emotional signals. Specifically, the interface application takes the electrical impulses and the waves generated as inputs, processes them and generates the measurements of the emotional signals over a period of time.

Figure 1 shows the Emotiv Insight device, which has five hydrophilic polymer sensors, which means that they must not be dampened for the waves to be transmitted. It facilitates the basic measures of mental performance in variables such as: engagement, stress, interest, focus, relaxation and excitement.

![Figure 1. Emotiv Insight device.](image-url)

The Emotiv Insight system integrates hardware and a software application that offers the functionality to measure the emotional signals of a person at the time of executing a specific activity. The emotional signals that the device measures are Interest defined as the degree of attraction or rejection of the activity that is being executed, engagement defined as the degree of immersion of a user in an experiment, stress defined as the degree of comfort that is presented in the experiment, relaxation defined as the ability of the brain to reach a calm state, excitement defined as the degree of emotional and alert enthusiasm that occurs mentally and physically, focus defined as the degree of attention that stays on task fixedly.

Specifically, for the experiment, an intentional sample of 5 male students between the ages of 20 and 24 years was used, who study in the academic programs of systems engineering and mechatronics engineering, Universidad de Pamplona, Colombia. For the application of the experiment, two texts were used, one in traditional format and the other in book format with augmented reality, which had as their scope in terms of contents the chapter of simple lists of the course of data structures and algorithms of the program of systems engineering from the Universidad de Pamplona, Colombia.

For the experiment, the Emotiv Insight device was installed and calibrated in each of the students and the emotional measurements were taken at two different moments, in the first moment the
measurements of the emotional signals were recorded by reading the chapter of simple lists in traditional format and in a second moment the measurement of emotional signals was carried out to the same students interacting with the chapter of Simple lists with augmented reality book format. To access the augmented reality applications of the AR book, the students used Smartphones with which they accessed the software applications of the chapter.

2.1. Capture of neuroseigns in reading and interaction with augmented reality books
The experiment used to capture emotional signals through a BCI interface was configured as follows:

2.1.1. Phase 1: Reading traditional text. The following procedure was used for each of the students in the intentional sample: The first activity that was executed in each experiment with the students was the installation and calibration of the Emotiv Insight device, for which the 5 sensors of the device were placed in the specific places on the head recommended by the manufacturer and then the correct installation was verified with the device application examining the connectivity with each of the sensors. Next, the Emotiv Insight device was calibrated, instructing the student to relax, take a breath and close his eyes for 15 seconds in order to reach a neutral state of relaxation to start the measurement of emotional signals in the reading process. traditional text.

Subsequently, the student was asked to read the first chapter of the traditional book and to answer an instrument on the content of the chapter. Finally, the measurements of the emotional signals recorded during the experiment were downloaded from the device application. In a complementary way, a process of segmentation of the levels of the emotional signals was carried out according to the activity, to segment the measures when the student interacted with the traditional textbook and the emotional signals when the student was answering the instrument on the content of the chapter.

2.1.2. Phase 2: Reading and interaction augmented reality book. The following procedure was used for each of the students in the intentional sample: In a second session, the device was installed and calibrated to the same students of the sample, in order to record the measurements of the emotional signals in the interaction with the chapter of simple lists of the book "dynamic data structures: the challenge of learn through an AR book ", in this chapter the student had to access by means of markers focused through the cameras of their Smartphones to two augmented reality applications that were intended to describe the concepts and processes of simple lists.

3. Results
The capture of the emotional signals by the Emotiv Insight device is carried out through the sensors and later they are registered in the app through Bluetooth communication. The general visualization of the measures of the emotional variables is recorded as shown in Figure 2. Specifically, the Figure 2 shows an overview of the measures of mental state in one of the students analyzed, from there the time of the test, the general graph of the behavior of the variables over time and finally, the six values of the variables in percentage.

![Figure 2. Overview of emotional variables of a student in an experiment.](image)
In a complementary way, the results of each of the emotional variables can be disaggregated as shown in Figure 3. Specifically, a time analysis is made on each variable taking the total experiment time obtained previously as 100% and on that, it divides into duration percentages as: high, medium and slow level. The results recorded for each of the emotional variables taken for each of the students in reading the traditional text compared to reading and interacting with the AR book are shown in Table 1.

![Figure 3. Disaggregated view of a student's stress variable.](image)

| Table 1. Comparative analysis of emotional signals. | Stress | Excitement | Engagement | Focus | Interest | Relaxation |
|--------------------------------------------------|--------|------------|------------|-------|----------|-----------|
| Reading traditional text student 1               | 31     | 23         | 52         | 35    | 49       | 26        |
| Reading AR student 1                             | 39     | 30         | 47         | 23    | 53       | 50        |
| Reading traditional text student 2               | 38     | 53         | 46         | 32    | 53       | 41        |
| Reading AR student 2                             | 40     | 47         | 50         | 26    | 54       | 45        |
| Reading traditional text student 3               | 44     | 27         | 59         | 45    | 52       | 42        |
| Reading AR student 3                             | 37     | 13         | 37         | 39    | 44       | 21        |
| Reading traditional text student 4               | 38     | 27         | 57         | 38    | 53       | 41        |
| Reading AR student 4                             | 38     | 33         | 59         | 40    | 53       | 35        |

As a result of the comparative analysis of the level of the emotional variables in a reading experiment in a traditional text compared to the reading and interaction of an AR book in Table 1, the following findings can be highlighted. The excitement of 50% of the population increases from reading in the AR book compared to reading in a traditional text. The engagement in 50% of the population increases from reading in the AR book with respect to reading in a traditional text. Interest in 66% of the population increases from reading in the AR book compared to reading in a traditional text. Relaxation in 50% of the population increases from reading in the AR book compared to reading in a traditional text.

In previous qualitative studies, aimed at knowing the educational possibilities of augmented reality in university education, it has been possible to determine that augmented reality applied to education allows activating cognitive processes in a proportion of 14.7% of the Higher education students according to the perception of students who have used augmented reality in training processes [11]. Similarly, it was possible to identify that certain applications of augmented reality are considered by students in a proportion of 12% as stimulators of attention, concentration, immediate memory, mediate memory and reasoning. The previous results have also been endorsed with educational experiences that enrich traditional printed texts with augmented reality applications [12]. In a comparative way, the study was able to identify that in 25% the concentration improves in the interaction with books with augmented reality with respect to the same variable in the reading of traditional texts.
Regarding motivation and enthusiasm, the students consider that the use of augmented reality is enhanced by 15.8% by promoting more motivating, collaborative and interactive training scenarios and helping a more open education [11]. When comparatively analyzing, in the study described it was possible to verify that enthusiasm increases by 50% in the interaction with books with augmented reality compared to reading traditional textbooks. The motivation generated by augmented reality in training processes has also been highlighted in different studies [13-15].

4. Conclusions

Brain-Computer Interface systems have become a mechanism that is part of a strategy for verifying the level of emotional variables in experiments from different disciplinary fields. In particular, this work evidenced the verification of the impact of the integration of an emerging technology such as augmented reality in the field of higher education through AR books. The hypothesis that the students' interest in reading, understanding and learning really increases when elements of augmented reality are integrated into the texts was verified through an experiment that, through the analysis of different emotional variables, allowed the generation of valid conclusions and supported in the results issued by the Emotiv Insight device.

The experiment developed in this work shows that interest in reading with AR texts is one of the variables that stands out the most in the implemented analyses and not only in the results of the Emotiv Insight but in the perception that students have of this variable. , that is to say; that the hypothesis raised at the beginning could be verified by ensuring once again that the interest of students is really awakened when they interact with an emerging technology such as augmented reality applied in a traditional text, this allows them to be more attentive and more relaxed at the moment of learning a new topic. Regarding the emotional variables, supported by the information collected in the experiment, it can be said that the integration of reality increases in traditional books and increases the interest of students of computer science in higher education regarding the reading of a traditional text.

The development of technological applications that integrate concepts such as augmented reality, mixed reality, virtual reality, immersion is increasingly being integrated with greater potential in the implementation of educational resources in all modalities and disciplinary fields of higher education in order to awaken interest, improve motivation levels, improve focus levels with respect to learning processes.

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