Analysis of cognitive states in response to stimuli from augmented reality applications for teaching physics

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Abstract. The scope of this article is to analyze the behavior of children's brain waves in response to interaction with an augmented reality application that aims to support the concept of measurement in physics teaching. In particular, the analysis of brain waves is carried out through a brain-computer interface that measures 6 cognitive states such as engagement, interest, stress, focus, excitation, and relaxation. The method used to perform the analysis is carried out by means of electroencephalography, which is an electrophysiological process to record the electrical activity of the brain, and which is captured by means of sensors located on the scalp. Once the signals are captured, they are amplified, digitized, and stored in a computer for processing and analysis. Initially, electrical signals are recorded in response to a measurement stimulus with traditional methods and later with an augmented reality application stimulus. Among the most relevant findings, it was possible to establish that interest and commitment increase in response to the teaching method supported with an augmented reality application for the measurement concept with respect to the traditional teaching method. The use of vision technologies in teaching the concept of measurement improves cognitive states of interest, commitment and reduces the level of stress.

1. Introduction

Mental processes are supported by electrical impulses generated by the synaptic connections of neurons in the brain. The recording of electrical impulses generated by the brain is carried out through a process called electroencephalography and the test in which these impulses are printed through brain waves is called an electroencephalogram. Thanks to the advance in the commercialization of electronic devices of the headband type, the recording and measurement of these electrical impulses can be carried out through non-invasive procedures [1]. The brain waves received when performing the electroencephalogram are classified according to the frequency band to which they belong, particularly the Delta wave handles a frequency range between 0.5 Hz - 3.5 Hz, the Theta wave handles frequency ranges between 3.5 Hz - 7.5 Hz, the wave Alpha handles frequency ranges between 7.5 Hz - 12.5 Hz, the Beta wave handles frequency ranges between 12.5 Hz - 30 Hz and the Gamma wave handles frequency ranges between 30 Hz - 60 Hz [2].

Regarding the structure of electrical signals in the brain, three types of activity associated with the presentation of sensory stimuli have been identified [3]. The first so-called spontaneous activity refers to electrical activity that is not associated with the presentation of stimuli, it is also known as background activity or noise. The second type is that of induced activity. Although this type of activity is correlated with the presentation of stimuli, it is not focused on phases and is not considered to carry relevant information from an experimental point of view. The third type is called evoked activity and is one that shows a direct correlation with the presentation of the stimulus and is focused on the phases. This type
of activity is the one that provides the most important information from the experimental point of view and its processing results in signals called evoked potentials (ERP) [1].

The sensory stimuli used in this research correspond to the interaction with the application of augmented reality for the subject of measurement by children and in comparison, with the measurement processes carried out through traditional methods. Specifically, augmented reality can be defined as a technology that integrates signals captured from the real world (typically video and audio) with signals generated by computers (three-dimensional graphic objects); makes them correspond to build new coherent worlds, complemented, and enriched [4]. On the other hand, at the interaction level, augmented reality consists of the interaction of graphics, sounds, and applications superimposed with the real world that are reproduced in real time [5].

The integration of the neuroscience field of knowledge with emerging technologies such as augmented reality makes it possible to identify the impact generated by the interaction of children with augmented reality applications in different disciplinary fields and moments of their training. Specifically, this work aims to answer the question: What is the impact on the cognitive states of engagement, attention, excitement, focus, relaxation, stress generated by the interaction of children with augmented reality applications to develop the concept of measurement in relation to traditional physics teaching methods?

2. Methodology and materials

The methodological approach used for the development of this work is exploratory-quantitative, using case analysis on a convenience sample. Specifically, the stages developed in the research process are shown in Figure 1.

Figure 1 shows the stages of the research process, for the selection of the children who participated in the experiment, it was considered that they were digital natives and that they had an acceptable degree of familiarity with Smartphone devices, later the experiment to be carried out was explained in detail to the parents to access their authorization, and the completion of the informed consent. The capture and recording of brain waves during the three moments of the experiment was carried out through the Emotiv Insight device, which has 5 sensors located in different parts of the scalp [6-8].
This device was selected because it is comfortable, easy to calibrate, low connectivity adjustment time, low cost and provides the emotional signal values during the experiment through the Emotiv PRO software. The collection, configuration and processing of the signal was carried out through a laptop with Bluetooth connectivity and Windows operating system. The Emotiv PRO application was used to record the brain waves of the experiment and the waves were subsequently exported to perform the analysis of the experiment data.

Specifically, in the stage of recording the neuron signals of the child performing a specific activity, brain wave measurements were taken in the child's interaction with a Smartphone device in a daily activity in order to have a reference point of the signals’ emotions of the child. At the stage of registering a child's neuron signals in the process of measuring an object using the traditional method, the child was asked to measure a bottle by means of a ruler. In the stage of registering neuron signals of a child in the measurement of an object by means of an augmented reality application, the child was asked to take the measurement of the bottle by means of an augmented reality application whose scope is to take measurements through the Smartphone camera and with a process of focusing and zooming in on the real object, which in this case is the bottle.

The described process was replicated in a 12-year-old boy to later proceed to the analysis of the results of the measurement of the emotional signals in the two experiments. For the analysis and discussion of the electrical signals recorded through brain wave patterns, the emotional signals recorded in experiment 1, experiment 2, experiment 3 were captured and stored through the Emotiv PRO software. Subsequently, through the view of cognitive states, the average measurements of the emotional signals were accessed during each of the experiments. Finally, the comparative analysis of the experiments was carried out and the correlation indexes of the emotional signals with the age of the children were analyzed. The process of acquisition of cognitive states is shown in Figure 2.

The process of acquisition of the emotional signals specified in Figure 2, begins with the placement of the Emotiv Insight device on the head of the subject who will carry out the experiment and then it must be connected with the Emotiv PRO software and proceed to configure it until obtaining superior connectivity. 95%. Once the connectivity is stable, we proceed to start the experiment and record the waves generated during the intervention or stimulus that is being executed, then the view must be changed to the emotional signals, which indicates the average of these signals. during the time the experiment was recorded.

![Figure 2. Cognitive states registration process.](image)

3. Results and discussions
The recording of brain waves through the brain-computer interface allows evaluating the reaction of users to the intervention of emerging technologies such as virtual reality [9,10], augmented reality [8,11,12], becoming an alternative method for measure the behavior of emotional variables such as commitment, excitement, focus, interest, relaxation, stress in the face of children's interaction with augmented reality applications to support the subject of measurements in physics. Additionally, the registration of the electrical signals of the neurons is registered by means of the sensors of the brain-computer interface and later these signals are processed and sectioned through algorithms supported in the Wavelet transform, allowing access to the indicators of cognitive states.

Specifically, in the work described the brain waves of a group of children were recorded in three moments of an experiment, in the first moment the emotional measures of the child developing a normal activity such as interaction with a telephone were recorded. In the second moment, the emotional signals
of the child were recorded by measuring an object with the traditional method using a ruler, in the third moment the same object was measured through an augmented reality application as can be seen in Figure 3.

The results obtained in the process of measuring objects with traditional methods and with augmented reality applications show that the emotional variables interest and relaxation increase slightly in the interaction of a 7-year-old child with the augmented reality measurement application in relation to the emotional variables recorded when interacting with the traditional methods used by children in school. In a complementary way, it is evident that the excitation and focus variables are slightly higher in the measurement process through the traditional method and the commitment and stress variables remain with similar indicators in the two measurement methods.

In a second experiment, emotional signals were recorded to a 12-year-old boy at the three moments of the experiment, obtaining the results recorded in Figure 4. In the experiment with 12-year-old children, the level of commitment is higher when measuring with the application of augmented reality compared to traditional measurement methods. In a complementary way, it is observed that the level of stress decreases in the interaction with the augmented reality application. Additionally, the interest and relaxation variables are considerably higher in the traditional measurement method in relation to the measurement method through the application of augmented reality. The variables excitation and focus remain with similar indicators in the two measurement methods.

In a complementary way, in the analysis of results, the Pearson correlation coefficients were calculated for the range of the averages of the emotional signals of the measurement experiment with traditional teaching methods correlated with the averages of the emotional signals of the measurement experiment with an augmented reality application, finding a result of 0.98745216 which indicates that there is a direct linear correlation between the ranges of values that were analyzed. Consequently, it can be said that the cognitive states associated with the emotional signal’s engagement, excitation, focus, interest, relaxation, stress in 7-year-old children increase when interacting with an augmented reality application to develop the concept of measurement in comparison with traditional methods of teaching the concept of measurement.

Similarly, Pearson's correlation coefficients were calculated for the range of the averages of the emotional signals from the measurement experiment with traditional teaching methods correlated with the averages of the emotional signals from the measurement experiment with an augmented reality...
application in 12-year-old children, finding a result of 0.37257667 which indicates that there is a less strong direct linear correlation between the ranges of values that were analyzed. Consequently, it can be said that the cognitive states associated with the emotional signal’s engagement, excitation, focus, interest, relaxation, stress in 12-year-old children increase slightly before a stimulus of interaction with an augmented reality application to develop the concept of measurement in comparison with traditional methods of teaching the concept of measurement.

4. Conclusions
The integration of augmented reality applications in the teaching processes of physics in children increases the indicators of cognitive states, particularly in the development of the measurement concept with the use of an augmented reality application, considerable increases were identified in the averages of the variables’ engagement, excitation, interest, focus, relaxation. The values of these variables were captured through a brain-computer interface which records the electrical signals generated by neuronal activity in response to stimuli such as interaction with augmented reality applications.

The use of brain-computer interfaces for the recording of brain waves and subsequent treatment to obtain emotional signals has allowed to verify the impact of interventions or stimuli in experiments, specifically they have allowed to measure the friendliness, usability, and reaction of individuals in terms of emotions in the interaction with different applications implemented with emerging technologies such as augmented reality.

From the results obtained it was possible to determine characteristic values of the emotional variables, engagement, excitation, interest, focus, relaxation, stress in the interaction of children with augmented reality applications that allow the development of physics topics such as measurement. Specifically, in 7-year-olds, interest and relaxation increased when interacting with the augmented reality application. In 12-year-olds, engagement increased significantly, and stress decreased when interacting with the augmented reality application. In a complementary way, the subjects of the experiment expressed their satisfaction and curiosity for accessing other augmented reality applications to support themes of the other subjects of their curriculum.

The subjects who participated in the experiments verified that the level of precision of augmented reality applications for measurement is highly like the results obtained through traditional methods, which implies that the level of reliability and functionality of this type of applications are very close to reality.

Figure 4. Emotional signals in measurement processes in 12-year-old children.
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