# Evaluating Engagement Physiologically and Knowledge Retention Subjectively through Two Different Learning Techniques

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**Abstract.** This paper describes the findings of a replication study conducted at a different location. This study measures the engagement level of participants objectively from two learning techniques: video game and handout (traditional way of learning). This paper may help other researchers design their own Brain-Computer Interface study to measure engagement. In addition, the results of this paper shows a correlation analysis between Engagement (measured physiologically) and knowledge measurement (subjective data). Further, this paper describes briefly the limitations of the Emotiv non-invasive EEG device, which may help researchers and developers understand the device more.

**Keywords:** Emotions in HCI, Brain-Computer Interface, Passive BCI.

## 1 Introduction

With the innovative and technological changes happening daily on a global stage, the consequences of having a poorly prepared work force could be staggering. In light of this conjecture, there has been a considerable amount of attention given to the American educational system. Discussions of international rankings [12], the effects of socioeconomic disparities [11] or preparation of teachers all serve as talking points in the effort to repair the current state of education. Frederick Hess, director of education policy studies at the American Enterprise Institute, a conservative policy think tank recently went on record stating that "We spend a lot of time debating pedagogies, a lot of time blaming teachers, a lot of time saying that there's a war on schools... I want to suggest that a lot of it actually misses what matters [16]." However this begs the question what does matter? In an age where information is far more attainable to the masses than ever before, how can our educational system be in such a crisis [3].

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USA Today columnist, Ruth Bettelheim has an answer. Bettelheim suggests more attention needs to be given to understanding how students learn. Furthermore, Bettelheim suggests that the educational failures can be mitigated by an overhaul of the traditional classroom based on the findings of cognitive neuroscience [4]. Likewise and following in the same order, researchers, professionals, and students all acknowledge the need for students to be engaged throughout the learning process [5]. It has been noted that students are bombarded with outside stimuli, causing a general lack of engagement towards the material. In response, educators and game designers have teamed up to provide more engaging experiences that have the advantage of maintaining attention by being entertaining. However, though these games may be entertaining, they cannot neglect instructional aspects that game is intended to serve [14]. As Nicholas Negroponte, the founder of MIT Media Lab points out "Many of the software products that are being developed for children today serve to narrow, rather than broaden, children's intellectual horizons [3]."

This has sparked interest in the evaluation of educational videogames and provides the background for this paper with the underlying question being: "Do educational video games really teach students, and if so how engaging are they? "[9,15]. Numerous works have measured engagement and information retention through assessments of educational video games and more traditional means such as textbooks. The growing amount of literature devoted to the use of games as educational tools serve as indicators of the popularity of this topic [8]. Research has repeatedly shown that in certain environments educational video games can be more attractive to students than traditional learning tools [6,10]. Moreover, studies have shown these educational video games do a better job at obtaining and maintaining student's attention [7]. However, there is no general consensus on which learning technique is more engaging, and which technique is best for knowledge retention. This paper discusses two studies that were conducted to investigate the overall student engagement and knowledge retention of an educational video game in comparison with a textbook that expressed the same information. The first study was conducted at a university in the Southeastern United States, where the results were reported [15]. Later, the replication of this study was conducted at a university in the Northeastern United States.

## 2 Experimental Design

### 2.1 Overall Design

The between-subjects design consisted of 32 participants (Male = 12, Female = 20). Participants randomly assigned to a group that received instruction via video game (15 participants) (figure 1) [17] or via handout (17 participants); a more traditional method of learning. Both groups received instruction about the Lewis and Clark Adventure. This combination allowed us to collect both subjective (traditional method to collect engagement) and objective data, in order to see if there was a correlation between both.

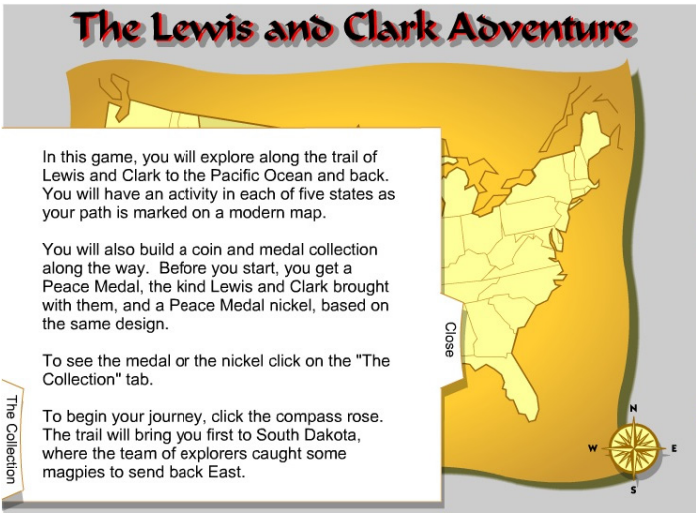


**Fig. 1.** The Lewis and Clark Adventure Game

### 2.2 The Physiological Apparatus

The Emotiv EPOC (figure 2) is a wireless EEG data acquisition and processing device. This device consists of 14 electrodes (AF3, F7, F3, FC5, T7, P7, P8, O1, O2, T8, FC6, F4, F8, AF4) to obtain the EEG signal and these channels are based on the international 10-20 locations. The international 10-20 System is the standard naming and positioning for the EEG measurements of any EEG BCI device. This device connects wirelessly via bluetooth and a USB dongle to a computer. This device was chosen among others for its portability, which may provide the best user experience.

This device was used to measure engagement (objective data). It was measured by the EmoStateLogger which was modified to measure engagement for a period of 20

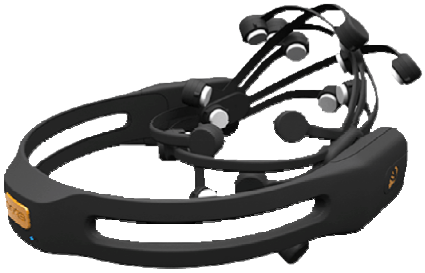

**Fig. 2.** Non-Invasive EEG Emotiv EPOC Device

minutes; the results were computed using Emotiv's proprietary engagement algorithm. The Emotiv engagement range is from 0 (not engaged at all) and 1 (very engaged). The EmoStateLogger is a C++ application bundled with the Emotiv Software Development Kit (SDK). The calculated engagement was saved into a text file where they could be further analyzed. In addition, the Emotiv control panel established a connection between the device and the computer.

### 2.3 Procedures

First a consent form was given, after gaining consent, a pre-assessment was administered to collect demographic information and to determine how much information they knew about Lewis and Clark before performing the task.

Once the pre-assessment was completed, the device was mounted. The amount of time taken to mount the device varied depending on the amount and type of hair of the participant. Although, this time were not recorded, it is important to noticed that it may take up to 15 minutes for certain participants, in order to mount the Emotiv device correctly and start obtaining affective data. Once the mount phase was completed, the experimenter gave instructions to perform the given task. Once the instructions were given, the participant started the task. As soon as the participant started the task, the experimenter started recording engagement with Emotiv. The task involved either playing the game or reading the handout. The same information was presented in both the game and in a handout. The participants performed the task for 20 minutes. After 20 minutes the experimenter stopped recording engagement and dismounted the device from the participant's head. Following the dismounting of the device a 10-question quiz was given in order to measure the knowledge they have acquired. Both groups were given the same quiz. After this quiz was administered, an assessment was given to participants to obtain self-reported information on how much they felt they had learned (knowledge increment), how engaged they felt during the given task, and how interesting they thought the information was.

## 3 Quantitative Results

In trying to gauge how engagement affects test scores a regression analysis was performed on the average engagement level of participants and their test scores. There was little correlation found between engagement levels and test scores. For the game condition $r^2 = 0.005$ and the handout was $r^2 = 0.002$. For this study, this finding suggests that there is little correlation between engagement and representation method and retention.

Table 1, represents the engagement average between the two groups. It shows that the game group had a slightly higher engagement average than the handout. In the previous report the handout group were slightly more engaged than the game group, unlike this second part of the study.

**Table 1.** Engagement Results

| Group | Sample Size | Engagement | Engagement STD |
|---|---|---|---|
| Game | 15 | 0.619 | 0.054 |
| Handout | 17 | 0.580 | 0.048 |

Table 2, shows the averages of the test scores and the anticipated test scores (ATS). It can be seen that the participants from the game group felt more confident on their performance than the handout group, but they performed worst than the handout. Interesting enough, the results reported on the first study conducted in the SouthEast, the handout group performend better in the test than the game group [15].

**Table 2.** Test Results

| Group | Sample Size | Test Scores | Test Scores STD | ATS |
|---|---|---|---|---|
| Game | 15 | 40.67 | 4.41 | 66.00 |
| Handout | 17 | 61.76 | 12.37 | 56.47 |

It is interesting to find some correlation in terms of test scores performance between two different set of population (Northeast and Southeast). In addition, the results were broken down into gender for further analysis.

### 3.1 Results by Gender

Table 3, demonstrates the engagement results by gender. It is seen that male were slightly more engaged than female in both groups. Comparing by same gender, both of them were more engaged in the game than in the handout. Although both genders were more engaged in the game, it can be seen from table 4 that the handout group got more information than the game group. Several assumptions can be made, but more studies are needed to clarify these assumptions.

- *First Assumption:* Male were more engaged than female in the game group because, male tend to like more video games.
- *Second Assumption:* Male were more engaged than female in both groups, because the contact between the Emotiv and the participant's scalp were more direct. Female tend to have more hair than male in many cases.
- *Third Assumption:* The participants from the handout group performed better in the test, because they were less distracted and just focused on the content, than playing the game itself.
- *Fourth Assumption:* The participants from the handout group performed better in the test, because they are used to the traditional way of learning, which is reading from physical paper (book, handouts, etc.) and they might not be used to learn from a video game.

**Table 3.** Engagement Results by Gender

| Group | Male Avg. | Male STD | Female Avg. | Female STD. |
|---|---|---|---|---|
| Game | 0.631 | 0.04 | 0.609 | 0.05 |
| Handout | 0.594 | 0.05 | 0.570 | 0.03 |

**Table 4.** Test Results by Gender

| Group | Male Avg. | Male STD | Female Avg. | Female STD. |
|---|---|---|---|---|
| Game | 45.0 | 20.73 | 37.7 | 14.81 |
| Handout | 57.14 | 12.53 | 65.0 | 11.78 |

## 4 Limitations

There are several limitations raised in this study that it is important to mention. The main limitation is the fact that the researchers did not know the details of the algorithm used to measure engagement. This proprietary algorithm is protected by the Emotiv Company and do not share any details with any researchers. Although, Emotiv is widely used, it is important to notice this issue, and correlate the physiological results with some subjective data or use an engagement formula, mentioned by Szafir, D., and Mutlu, B. [18]. The second limitation with Emotiv, it is the limitation with many non-invasive EEG BCI devices. People have different texture and length of hair, which interfere with the direct connectivity between the device and the scalp. Therefore, it is hard to obtain really good signal to obtain affective data. Also, reported by Ekandem et. al., it may require a long time to mount the device and establish an adequate connection, this varies per participant.

Further, some participants reported that after a while (specific time was not recorded), the device was hurting a little bit from the sides as something was grabbing their head. This may affect the performance of the user while trying to learn information, because they might feel some pain, which may lead to lack of concentration.

## 5 Conclusion

This paper provides a brief information on the misperception and the needs of finding an accurate learning technique. It also provides a study conducted in order to show as a basic guideline to other researchers of how BCI may be implemented towards their educational studies.

Further studies are needed to come up with conclusion in which method of learning is better or preferable by users: video games or the traditional way of learning. It is recommended from this paper to implement objective measurement to any educational studies, which may lead towards better understanding of the learners. The study presented in this paper may be applied to other studies and modified to the appropriateness of their methods. Lastly, this paper raises some research questions, which may be investigated in other studies.

- *First Question:* Physiologically speaking, while measuring engagement with an EEG non-invasive device such as Emotiv, do engagement results differ by the different texture and length of hairs?
- *Second Question:* While measuring engagement with an EEG non-invasive device such as Emotiv, do engagement results differ by the different sizes and shapes of human's head? How does it differ and what is the difference?
- *Third Question:* How does engagement differs objectively between different cultures or ethnicities while learning in different learning techniques? Can Passive Brain-Computer Interfaces help us understand better the behavior within a task by different cultures?

These questions were based on observations and comments made by the experimenters while the participants were performing the task. Therefore, further studies are recommended in order to understand and develop, concrete methodologies to implement EEG measurement of engagement in educational techniques.

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