The Experience and Cognitive Performance as a Gamer During the Use of Educational Video Games

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Abstract: *Video game* have surged in popularity and usefulness in education; higher-education institutions have seen an increment in student's interest on interactive content for learning complex subjects, especially in the field of engineering. This study explored the effects of emotions and cognitive performance during the use of serious games. **Methodology:** A quasi-experimental approach was used to assess cognitive processing during the execution of a challenging matrix-related activity within undergraduate engineering students (n=9). An initial baseline was made on emotional dimensions through the EMOTIV software and later analyzed to evaluate student's cognitive load through a semi-structured interview. **Results:** Six basic emotions were identified: commitment (24.31%), relaxation (21.7%), emotion (21.04%), interest (12.43%), focus (16.31%), stress (9.25%). Cognitive dimensions emerge such as effort, frustration, performance, mental demand, physical demand and temporal demand. **Conclusion:** higher task commitment is identified when students utilize serious games and cognitive performance is mediated by individual adjustments to video game's complexity.

Keywords: Educational videogames, Emotiv EPOC, User Experience, Cognitive Load.

1 Introduction

The high capacity of immersion generated by video games has purged geographical boundaries and age groups regardless of socioeconomic conditions. For instance, it is noteworthy mentioning that the American entertainment software Association recently featured that 75% of the general population has at least one video game at home, with the majority of users being 18-34 years old [1]. Furthermore the increasing advent of educational *games* "serious games" in higher education [2], compared to the first entertainment-driven games, had led to changes in the market. Hence, this aforementioned evolution is frequently described as a sound response given the high-pitched demand to respond to educational requirements among students [3].

How the teaching content is displayed makes a difference to the learner experience [4]; [5]. While in the teaching experience it is common to find low indicators of participation, poor student interest in overly complex courses; the popularity of video *games* has validated for the implementation of educational content as a learning strategy. For example [6] demonstrated the effectiveness of implementing a constructivist educational model for courses with low-student interest, succeeding greater participation and sense of achievement by expanding video *games* for teaching. It is believed that school-related content's appropriation is of paramount when acquiring new information, and that is advanced when the student becomes the main protagonist of their own knowledge building toward a more meaningful learning process [7] while relating with interactive tools such as video *games*. Therefore, educational video *games* are of great importance for imparting complex theoretical content, especially for thought-provoking task or tasks involving decision making.

Pedagogical model for learning based on digital games

The Transformational Game Theory (TGT) proposed by [7] provides a robust basement to sustain the impact of a *"perceptually and semantically enriching"* learning content on student's cognitive performance. Although several teaching methodologies have tried to offer explanations of how it is better to teach, the TGT theory is one that proposes a better, guided framework to explain meaningful learning by integrating a virtual context, people and educational content. In this study we focus on the video game as a learning environment that enhances and / or activates the learner's proactivity, positioning the educational video game platform as a context that provides greater opportunities for participation and reinforcement of content, compared to a traditional classroom.

Generating immersive strategies to involve students into their self-learning process is not a contemporary controversy. Systematic studies refer about the existing constraint across educational institutions to offer enriching educational experiences; Moreover, in view of the insufficient deployment of interactive methodologies, the usage of educational video *games* may potentially bring into line the student, the content and the pedagogical context effectively [7]. The same authors report higher levels of commitment and motivation to learning through educational courses, based on video *games*, which appear to be promising in the development of problem-solving skills.

Serious Games in Teaching Programming

"Serious *games* are (digital) games used for purposes other than entertainment only"[8]. These tools stimulate learning by facilitating feedback through an interactive environment. On the other hand, game programming has managed to capture the attention of students in the fields of computing, but also in other fields of education. Also, this sort of *game* programming provide useful tool to instruct programming students toward programming [9].

Some examples can be found in Hilton and Janzen [10], whose research demonstrated the effectiveness of serious games to teach divisibility through Zombie-based activities. Likewise, immersive journeys had proven being effective to solve real issues. For instance the literature reported the “Circuit Wars”, where electronic engineering students were immersed into tangible situations; students were expected to repair logic circuits effectively against the clock, the game used a didactic approach through varied complexity puzzles responding to student’s progressive knowledge and domain [11].

Effects of emotions and cognitive performance during exposure to video games

Given the wide range of complex, cognitive processes that take place in the human being, some reports depict the great value of improving their performance [5]. Its identification is relevant not only for measuring academic results [4], but also for exploring student’s motivation towards learning [12]. In fact, related research suggests that cognitive processes, such as attention span [13], and sense of peer collaboration may be enhanced in learners by using digitalized *games*. This aforementioned had been reported in Hughes, who described higher rates of homework engagement and skill improvement when using video *games*, in an 8-week experimental study with elementary school students [14].

Evidence on video *games*’ devising effects on human emotions and cognition support this study. For instance, Snodgrass et all, registered greater wellbeing on continuous videogame players. The author hypothesized that, emotions generated from the virtual experience may go even beyond the “well-being threshold”, whose effects interestingly may have an impact on the immune scheme. Another study measuring creativity report association between action videogame, inventiveness and flexibility, it is clear then that videogame involvement significantly generates positive emotions [5, 13, 15]. Individual differences may play a role on emotions and cognitions. Specifically analyzing the "theory of cognitive load" it is noticed that performance will largely depend on the level of mastery of content. Thus, as long as the learner is novice, he or she will require greater cognitive demand to solve the tasks appointed by the tutor [16].

This study contributes to the understanding of educational video *games* and their effects on emotions and cognitive processing, those experienced during the student's learning process. Given the current ongoing challenge of engaging students into educational activities, video *games* perfectly allow enhancing the learning experience by providing enjoyable activities to keep absorbing content [17]. Moreover, as stated in the “flow experience” model proposed by Novak and Hoffman [18], It appears to be relevant to explore the student's control perception over their task and the underlying level of complexity that might predict the level of participation in their learning experience. Under this context, players are better aware of their own capability to take decision on virtual environments with real challenges, combining formal instruction and experiential assessment [12].

In addition to exposing students to serious *games*, the researchers in this study exposed students to a semi-structured interview by asking participants about their subjective experience after their immersion in the video *game* designed by UCSM researchers. The following questions were asked: (1) Does the level of complexity in video *games* predict the increase of cognitive resources? (2) Do emotional responses predict the level of immersion in gaming-based learning contexts? (3) How does game-based teaching influence emotions and cognition?

The paper is organized as follows; second section presents methods for this study. Third section presents the procedure; the fourth describes statistical analysis and fifth describes the discussion and results. After that, we present our conclusions.

2 Methodology

2.1 Participants

First-year undergraduate students enrolled at the school of Systems Engineering participated in the program (n=9). Recruitment criteria were limited to male students because of the low female population in the program. The participants (mean age = 19 years) were instructed to use the video game "Engineers Escaping" to solve engineer-related challenges. Parallelly, the emotions of participants were measured through an advance hardware sensor "EMOTIV EPOC” located on the forehead section of each student. Furthermore, the participants took part on a semi-structured interview to identify the cognitive load experienced after the *videogame* exposure.

2.2 Materials

2.2.1 Emotion assessment through “EMOTIV EPOC” hardware

The “EMOTIV EPOC-EEG” (electroencephalograph) is a brain activity map hardware to identify cognitive processes, which may be experienced during the use of *videogames*. Emotions such as: relaxation, interest, focus, commitment, emotion, stress were analyzed. This device has 14 electrodes (saline solution sensors) located in AF3, AF4, F3, F4, F7, F8, FC5, FC6, P7, P8, T7, T8, O1, O2 and two additional sensors that serve as reference channels (one for the left and one for the right hemisphere of the head). The 14 data channels of the Emotiv EPOC-EEG collected data on emotional dimensions during the use of a software.

2.2.2“Engineer scaping” serious game

“Engineers Escaping” is a video *game* that exemplifies a real situation in the daily life of a systems engineering student. The story begins in the classroom of a programming course, where the protagonist discovers a tape that indicates that the engineers had been kidnapped and must rescue them. As part of the story, it should be noted that the student (character) will depend on the performance of the same within the video game. The main character is a boy who will represent the player; he will be able to move around the platforms, collect clues and crystals.

This *game* is built on particular principles. For instance, there are clear goals, alongside a level-based story which is straightforwardly described for students to feel that they have a challenge to pursue. The platform provides immediate feedback to player, who must jump and avoid obstacles to reach checkpoints showed through a progress bar on the screen. The *game* involves some basic skills to use the control command unlike other *games* platform. Moreover, the game poses a horror-based style to provoke tension on associated traps in each level (see Fig.1).

Fig. 1. “Engineer Scaping” game- control panel.

The serious game: Engineers Escaping was implemented to achieve motivation in learning matrix-based programming, testing, algorithm design, and geometric transformations. Each game level is organized in chapters whose main character must go through, the user will find traps that must be avoided or deactivated. In this scenario, there are controls which requires solving puzzle to disarm the traps and progress while collecting crystals and clues that contain key information. The character will be able to jump, move left or right, open doors within each floor or level. There are specific saws such as electric, lasers, spiked platforms that made levels difficult. Additionally, the controls are designed to deactivate the traps in the room; these controls contain puzzles that must be solved to advance in the level. Upon reaching the door, students must press the "e" key, which will take the user to the first puzzle of the game, which requires deciphering the combination in a 3x3 matrix by pressing specific color-based boxes (See Fig. 2. Test cases).

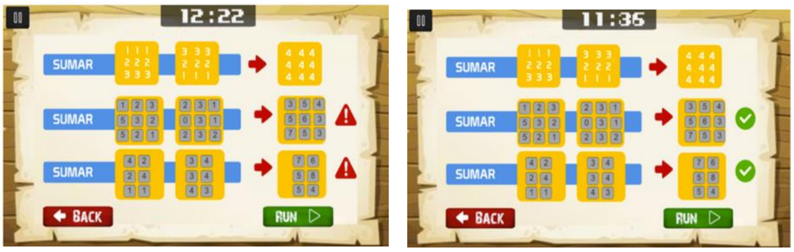

Fig. 2. On the left: Test cases in which the student has failed.
On the right: Successful test cases unlock the level and move on to the next.

2.2.3 Cognitive load interview

The Task Load Index Scale of the National Aeronautics and Space Administration (NASA-TLX Scale) was chosen to determine the perception about cognitive workload during the use of the video game "Engineers Escaping". The instrument measured 6 categories: effort, frustration, performance, mental demand, physical demand and temporal demand in the participants. Each of the items was reported at low or high levels, in the form of a semi-structured interview.

The NASA-TLX Scale was developed by Hart and Staveland in 1988 [19] to quantify the physical and mental workload associated with the performance of a given task, allowing the assessment of possible interference. The Scale has demonstrated a very low variability of intervening variables, due to its category weighting system that takes into account the individual's self-reported strengths and weaknesses.

3 Process

It should be mentioned that before the study commences, the approval of the local ethical committee of the Catholic University of Santa Maria was obtained, in addition to the written consent of each participant. Participants received information to partake in the study. They were informed about the study objective and its implicit risks.

They were seated in a comfortable chair and given a personal computer to use the video game. Investigators explained detailed instructions to take part on the video game "Engineers Escaping" for 60 minutes and that they had to advance as much as possible in the game (a platform game aimed at understanding different programming concepts applied in the early years of the career). For the real evaluation, each participant started the game in the computer lab. While the participant was playing on the computer, the lights were turned off to help immerse the player in the game and reduce the brightness of the room lights. The examiner installed and verified the connections between each electrode of the EMOTIV EPOC device and the student's scalp.

Emotional dimensions were captured in sync with the EEG data as the game is deployed. Then data was recorded on the same computer with all non-essential programs closed. After completion of the initial task ("Engineers Escaping"), participants were informed that they would undergo an interviewing process, where they would be asked about the cognitive load they were exposed to.

4 Statistical analysis

Descriptive statistics have been used to determine differences between participants and to characterize the variables measuring cognitive demand and emotional response to *videogames*. The statistical package SPSS 20 was used for quantitative analysis.

4.1 *Quantitative analysis*

Descriptive statistic was used to analyze emotions, whose dimensions are a) relaxation (21.7%), b) interest (12.43%), c) focus (16.31%), d) commitment (24.31%), e) emotion (21.04%), and f) stress (9.25%). It should be noted that a greater percentage of the “engagement” dimension (24.31%) is observed with respect to the other dimensions measured by the EMOTIV EPOC brain activity software. Additionally, the "stress" dimension has not had variability, which means it had been maintained in the pre and post assessment (*fig. 3*).

We also analyze normality using statistical package SPSS 20 (*see fig. 4*), we obtained that the data is parametric, particularly the dimensions of: stress and focus are even more homogeneous with respect to data normality. When comparing performance in the pre and post-test, we identified a student t-score of 0.038, with a variation of 4.2 points of the pre and post intervention (*fig. 5)*. It is important to emphasize that in the post-test, the dispersion of data in the evaluated sample is reduced.

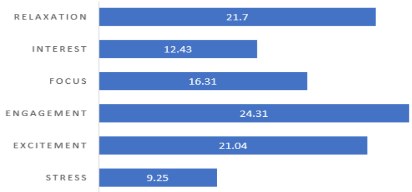

Fig. 3. EMOTIV EPOC Variation.

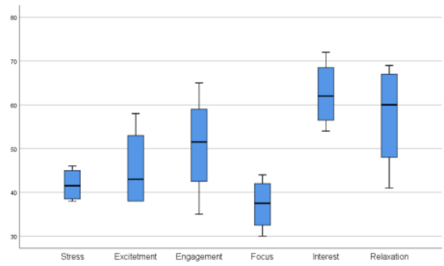

Fig. 4. EMOTIV EPOC Normality

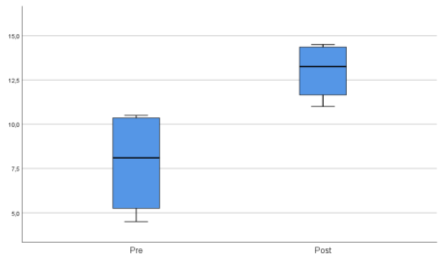

Fig. 5. Comparison Pre & Post test

4.2 *Qualitative analysis*

After collecting data from semi-structured interviews to investigate cognitive workload. A content analysis technique was used to examine the response patterns of the interviewees [20]. This methodology identified most of the recurring responses to classify the data into categories (*see table 1*).

The content obtained from the interview went through an initial categorization process guided by the "cognitive load" test (6 categories) classified into two levels (high-low) for each cognitive load category. The exploration contained the following dimensions:

Category **1. Mental demand,** in this category it is evident that, the greater the complexity of the challenge level in the video game, the greater the mental demand, in terms of mental concentration.

Category **2. Physical demand,** we found non-levels of physical activity, because the participants are in a sitting position in front of the monitor to access the video game.

Category **3. Temporary demand**, while some participants describe moderate-high pressure to finish the game within the stipulated time frame, others comment that the time is adequate for the task assigned in the game.

Category **4. Effort**, the responses obtained in this element are determined by individual differences. Some participants mention the effort to pass each level of the

video game, on the other hand, we find students who give greater value to the entertainment role, while "have fun" playing, the effort is implicit in the game.
Category **5. Frustration**, in this element we explored the feeling of discomfort-satisfaction with their own performance, while some students are frustrated by not completing all the levels of the video game, others express discomfort-anxiety at feeling observed by other players and not "reaching the good level" expected.
Category **6. Performance,** this element allowed us to find that some students experience a sense of success by participating in the platform, and since it was an educational game it imposed a different challenge in reference to the entertainment games, they are used to participate in. On the contrary, we found that some other students are dissatisfied because they could not complete the objectives and/or levels of the virtual challenge.

Table 1. Cognitive demand categories

Categories	Low	High	Notes
1.Mental demand	X		The activity has a light demand, it is an easy activity with instructions and guidelines.
2.Physical demand	X		The activity does not contain physical activity, except for typing and sustained sight.
3.Temporary demand		X	High and constant time pressure, time was limited for activities.
4.Effort			The activity requires incremental effort over time as work levels escalate.
5.Frustration		X	As work levels increment, incremental frustration is also reported. Irritability when not finding patterns in the game
6.Performance		X	The activity requires incremental effort over time. The user's performance responds to the incremental complexity.

5 Discussion and results

Transformational play has been positioned as an innovative tool that offers to enhance the learning experience [14, 21, 22]. The proven effectiveness of educational digital *games* in academic performance accelerates potential improvements in the way knowledge is transmitted [23].

These basic findings are consistent with previous research showing that varied emotional responses are generated during the exposure to educational *videogames*. We found MacMahan who evaluates the experiences of participants with assorted modes of stimulation and suggests that the Emotiv EPOC is a tool that evaluates the experience of the player during the game being an accessible tool because of its low cost [5]. While this study found higher levels of engagement during execution of activities, the multiple emotional and cognitive reactions will largely depend on the type of game. This is corroborated by Brilliant et al. [24], who describes categories of *games* such as "3D adventure, first-person shooting (FPS), puzzle, rhythm dance, and strategy" and its wide-ranging influence on the brain activity. Additionally, our study casts a new light on demonstrating the deployment of a guided *video game* of strategy called "Engineers Scaping" by involving first -year university students. This *video game* provides evidence to manage complex content, such as matrix programming and geometric transformations, through more didactic methodologies for data programming. Although the video content was enjoyable, the authors declare challenges on maintaining motivation and attention span among students.

Cognitive processing among students is of paramount to guide teaching methodologies. It is widely known that virtual and non-virtual content imposes a significant burden on the students' ability to receive and process information [23]. Particularly, the task performance resulting from mental effort by using online *videogame*s has been reported in numerous studies where the design, presentation and evaluation of content had raised multiple interventions in education. One of the points of analysis for this research is the NASA-TLX scale, which was reported as a relevant tool to identify subjective perception resulting from complex content exposure [25, 26].

The following contributions are evidenced in the area of educational research: a) videogame-based teaching improves student's motivation to analyze cases before the solution, as already reported in previous studies [10], b) students might better design and cognize the access and withdrawal of complex algorithms by providing a block-based structure [8]. Furthermore, this study demonstrated the importance of c) having a fairly clear and intuitive feedback to improve the ability to identify and diagnose problems timely [9].

The limitations of the present studies naturally include the sample size. Because of lack of a specialized video-game laboratory, we decided to include a short sample to control better the experience of gamers while learning complex contents. Another limitation is the availability of female students at the School of system engineering. Hence, this study involves the issue of not considering gender differences.

Despite these limitations, some implications of this study are raised. Results demonstrate that emotions make an impact on the way students process new information. As discussed, game-based curriculum should be considered on the basis of positive emotions such as engagement to allow students better involvement on their own learning [7, 27, 28]. Finally, more attention is needed on the game-based learning-teaching approach [22], given students not only need guided content but also digitalized learning environments to enhance a meaningful education in the context of real-problem solving.

6 Conclusion

This study identified the emotional dimensions and cognitive load during the use of a serious game called "Engineers Escaping". The findings depict a sort of emotions, which are manifested in the context of virtual learning. These emotions are stress, excitement, commitment, focus, interest and relaxation.

Furthermore, in the qualitative analyses it is found that cognitive performance depends on the levels of exposure to the game, confirming the hypothesis that, the *videogames* complexity increases the use of cognitive resources. These results are supported by previous studies that distinguish the subjective disparities in terms of emotional responses and cognitive load. Finally, it is critical to carry out more longitudinal research to capture the role of video games, emotions and cognitive resources to predict academic attainment on young university students.

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