

Exploring the Effects of Prior Video-Game Experience on Learner's Motivation during Interactions with HeapMotiv

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Abstract. This study explores the effects of prior video-game experience on learner's motivation in a serious game environment. 20 participants were invited to play our serious game, called HeapMotiv, intended to educate players about the heap data structure. HeapMotiv is comprised of three missions (*Heap-Tetris*, *Heap-Shoot* and *Heap-Sort*). We used Keller's ARCS theoretical model of motivation and physiological sensors (heart rate, skin conductance and electroencephalogram) to record learners' reactions during interactions with different missions. Results from non-parametric tests supported the hypothesis that physiological patterns and their evolution are objective tools to directly and reliably assess effects of prior video-game experience on learner's motivation.

Keywords: Motivation, serious games, prior experience, physiological sensors, electroencephalogram (EEG).

1 Introduction

Even though motivation within learners tends to vary across subject areas, educators consider motivation to be desirable and to result in better learning outcomes. In Intelligent Tutoring Systems (ITS) context, learners' interactions with systems and especially Serious Games (SG) have always been considered to be intrinsically motivating. However, learners' negative emotions or amotivational states, such as boredom or disengagement, have been known to appear following a certain period of these interactions and possibly elicit motivational problems or even cause the learners to start "gaming" the system. Having tools to assess learner's motivation during interactions with ITS is important to reduce, and eventually repair, motivational problems. Indeed, tutors can adapt their strategies and interventions and respond intelligently to learners' needs, objectives and interests.

Furthermore, efforts to overcome learners' motivational problems have mainly been focused on tutor's strategies or instructional design aspects of the systems. For example, Hurley [1] developed interventional strategies to increase the learner's self-efficacy and motivation in an online learning environment. She extracted and then validated rules for interventional strategy selection from expert teachers by using an

approach based on Bandura's Social Cognitive Theory and by observing the resulting learners' behaviour and progress. Goo and colleagues [2] showed that tactile feedback, sudden view point change, unique appearance and behaviour, and sound stimuli played an important factor in increasing students' attention in virtual reality experience. Arroyo and colleagues [3] evaluated the impact of a set of non-invasive interventions in an attempt to repair students' disengagement while solving geometry problems in a tutoring system. They claimed that showing students' performance after each problem re-engages students, enhances their learning, and improves their attitude towards learning as well as towards the tutoring software.

Some researchers have also found out strategies that teachers use in order to facilitate students' motivation toward tasks and goals of learning process. Teachers usually report that the proficiency in tasks may vary considerably depending upon the learners' familiarity and prior experience with themes, concepts, genre, characters, etc. Brandwein [4] clarified that teachers provide familiar tasks for students to construct understanding by connecting what they know with the essentials they are trying to learn. Wiley [5] defined interest as the state a student is in when s/he desires to know more about a subject and claimed that a student can be more interested in something s/he already knows about. He assumed that learners basic grounding in the subject and prior experience catalyze the construction of new, more coherent knowledge. He proposed to gain the interest by using concrete, real-life examples which will be familiar to the students, or when that is difficult, by using allegories or metaphors. Other studies have nevertheless shown that the creation of unfamiliar situations and events and paradoxical or conflicting experiences for the student facilitates attention and engagement (e.g., [6]). The learner's readiness to persevere when faced with unfamiliar and challenging learning situations opens up opportunities for success and achievement. Understanding the effects of prior experience on learner's motivation is of particular significance for our research work. In this paper, we precisely aim to assess the effects of prior video-game experience on learner's motivation during interactions with our SG called HeapMotiv. Our experimental study combines psychometric instruments with physiological recordings, namely heart rate (HR), skin conductance (SC) and electroencephalogram (EEG). We ask the following research question: What are relevant physiological patterns during learner's interactions with different missions of HeapMotiv and how are they correlated with learner's motivation and prior video-game experience?

2 Prior Video-Game Experience and Learner's Motivation

We developed a serious game, called HeapMotiv, which intends to educate players about the binary heap data structure. HeapMotiv is a 3D-labyrinth that has many routes with only one path that leads to the final destination. Along the paths of this labyrinth, several information signs were placed to help learners while finding destination. A learner has to play a mission before obtaining a sign direction. In its current version, HeapMotiv is comprised of three 2D-missions (*Heap-Tetris*, *Heap-Shoot* and

Heap-Sort), each intended to educate players about some basic concepts of binary heap, general purpose properties and application to sort elements of an array.

In the present study, we explore prior video-game experience in terms of the match between each mission of HeapMotiv and the learner’s previous experience with video games. From this viewpoint, a mission that involves objects and rules from a well-known game is considered as familiar and will be attributed to “with prior experience” class, whereas that involves objects and rules not consistent with previous learner experience is classed “without prior experience”. The common-sense assumption was made in the present study in order to divide different missions into with and without prior experience classes.

Mission	Description	Class
<i>Heap-Tetris</i>	It is based on traditional Tetris game where a learner has to move nodes during their falling using the arrows to fill a binary tree without violating the heap property.	“With prior experience” (Everybody is previously familiar with Tetris which is one of the greatest games of the entire time.)
<i>Heap-Shoot</i>	It is based on shooter games. A learner has to spot violations of shape and heap properties and has then to fix these violations by shooting misplaced nodes.	“With prior experience” (Most commonly, the purpose of a shooter game is to shoot opponents and proceed through missions without the player character dying. A common resource found in many shooter games is ammunition.)
<i>Heap-Sort</i>	It is a comparison-based sorting algorithm to create a sorted array. It begins by building a binary heap out of the data set, and then removing the largest item and placing it at the end of the partially sorted array.	“Without prior experience” (Although sorting algorithms were widespread used in different applications, their relative unfamiliarity impeded their acceptance for non computer science students. Heap-sort is then an unfamiliar algorithm compared to selection and insertion sorting algorithms.)

Table 1. Classification of missions of HeapMotiv

Furthermore, the ARCS model of motivation [6] has been chosen to theoretically assess learner’s motivation. Keller used existing research on motivational psychology to identify four categories of motivation: *Attention, Relevance, Confidence* and *Satisfaction*. We have also used objective measures that are not directly dependent on a learner’s perception. In our empirical approach, we relied on two non-invasive physiological sensors: HR and SC. These sensors are typically used to study human affective states. However, we decided to add another interesting and important sensor: EEG. Indeed, brainwave patterns have long been known to give valuable insight into the human cognitive process and mental state. More precisely, our EEG analysis relies on the “attention ratio” or *Theta/Low-Beta* which is widely used in neurobehavioral studies [7]. According to [7], low-level attention is characterized by “a deviant

pattern of baseline cortical activity, specifically increased slow-wave activity, primarily in the theta band, and decreased fast-wave activity, primarily in the beta band, often coupled". It is also common knowledge within the neuro-scientific community that investigations of cerebral activity limited to one area of the brain may offer misleading information regarding complex states such as attention and motivation. We have therefore investigated different cerebral areas to study simultaneous brainwave changes.

3 Experiment

Twenty volunteers (10 female) were invited to play our serious game HeapMotiv in return of a fixed compensation (mean age was 23.7 ± 6.8 years). They had no prior knowledge of heap data structure. Almost all participants said they were either very or fairly familiar with Tetris (100%) or Shooter (78%) games while only 7% of them have been familiar with some kind of sort algorithms. This is consistent with our assumption in the classification of different missions in section 2.

Following the signature of a written informed consent form, each participant was placed in front of the computer monitor to play the game. SC and HR sensors were attached to the fingers of participants' non-dominant hands, leaving the other free for the experimental task. EEG was recorded by using a cap with a linked-mastoid reference. The sensors were placed on four selected areas (Fz, F3, C3 and Pz) according to the international 10-20 system. The motivational measurement instrument called Instructional Materials Motivation Survey IMMS [6] was used following each mission to assess learners' motivation. Due to time constraints and in order to achieve minimum disruption to learners, we used a short IMMS form which contained 16 out of the 32 items after receiving the advice and approval from John Keller. 10 pre-test and 10 post-test quizzes about general knowledge of binary tree and knowledge presented in HeapMotiv were also administered to compare learners' performance. All participants have played each mission three times and have completed the game. EEG was sampled at a rate of 256 Hz. A power spectral density was computed to divide the EEG raw signal into the two following frequencies: *Theta* (4-8 Hz) and *Low-Beta* (12-20 Hz) in order to compute the attention ratio (*Theta/Low-Beta*) as described above. We also computed an index representing players' physiological evolution throughout the mission with regards to each signal signification. This index, called Percent of Time (*PoT*), represents the amount of time, in percent, that learners' signal amplitude is lower (or higher) than a specific threshold. The threshold considered for each signal is the group's mean signal. The *PoT* index is a key metric enabling us to sum-up learners' entire signal evolution for a mission.

4 Experimental Results

First, we report general results regarding learners' learning and motivation during interactions with different missions. We administered pre-tests and post-tests questionnaires pertaining to the knowledge taught in HeapMotiv and compared results.

The Wilcoxon signed ranks test showed a significant positive change in learner's performance in terms of knowledge acquisition ($Z=5.03$, $p<.001$). Furthermore, significant differences for the general motivational scores as well as some categories of the ARCS model were also observed between two mission classes. Results of Wilcoxon signed ranks tests showed significant differences of reported *Attention/Confidence/Motivation* scores between *Heap-Tetris* and *Heap-Sort* missions (*Attention*: $Z=-2.59$, $p<.01$; *Confidence*: $Z=-2.53$, $p<.01$; *Motivation*: $Z=-1.93$, $p<.05$). Similar result have been found between *Heap-Shoot* and *Heap-Sort* missions, *except* for the *Attention* category (*Confidence*: $Z=-2.36$, $p<.05$; *Motivation*: $Z=-1.89$, $p<.05$). However, no significant differences for *Heap-Tetris* and *Heap-Shoot* missions, *except* for the *Attention* category ($Z=-2.02$, $p<.05$).

Second, we report results of correlation run on physiological data recorded during learners' interactions with different missions of HeapMotiv. Analysis of "with prior experience" class (*Heap-Tetris* and *Heap-Shoot* missions) showed that significant relationships between the *Attention* category and *PoT-F3* and *PoT-C3* indexes, as well as the general motivation and *PoT-C3* index (*Attention/PoT-F3*: spearman's $\rho=.49$, $n=40$, $p<.001$; *Attention/PoT-C3*: spearman's $\rho=.44$, $n=40$, $p<.01$; *Motivation/PoT-C3*: spearman's $\rho=.32$, $n=40$, $p<.05$). For "without prior experience" class (*Heap-Sort* mission), significant correlations have been found between motivation and *PoT-SC* index, as well as *Attention* and *PoT-F3* and *PoT-C3* indexes (*Motivation/PoT-SC*: spearman's $\rho=.51$, $n=20$, $p<.001$; *Attention/PoT-F3*: spearman's $\rho=.44$, $n=20$, $p<.01$; *Attention/PoT-C3*: spearman's $\rho=.36$, $n=20$, $p<.01$).

These results positively answer our main research question (What are relevant physiological patterns during learner's interactions with different missions of HeapMotiv and how are they correlated with learner's motivation and prior video-game experience?). Learners were more interested in something they already know about and consequently had high motivation during *Heap-Tetris* and *Heap-Shoot* missions. The *Heap-Sort* mission which belongs to "without prior experience" class led to a lack of learners' attention and confidence. One explanation may be that difficulties, doubt, and initial failure have been known to appear during learning a new skill or confronting unfamiliar challenges. Furthermore, effects of prior video-game experience on learners' attention and motivation can reliably be monitored and related to changes in the *PoT* of skin conductance and EEG F3 and C3 areas. However, even the significant differences between *Confidence* scores that learners were reported for two mission classes, non-significant correlation results between the *Confidence* category and physiological data have been found. This suggests that the potential of only using physiological analysis in our comparative study is limited because, up until now, we cannot totally rely on physiological assessment in the identification of the effects of prior video-game experience on general learner's motivation (or ARCS categories). One reason may be the limitation of the attention ratio (*Theta/Low-Beta*) which seems to be inappropriate to identify EEG patterns other than those correlated with the *Attention* category.

5 Conclusion and Future Work

In this paper, we have assessed the effects of prior video-game experience on learner's motivation. Results have shown that a mission that involves objects and rules from a well-known game and most closely matches previous experience seems to elicit specific physiological trends in learners, especially observable in the attention ratios. Our results seem to show the relevance and importance of adding the EEG in our empirical study. The present work is capable of extension in several directions. Regarding the physiological analysis, it is preferable to explore alternative EEG frequency ratios based on additional brainwaves such as *Alpha* (8-12 Hz) and *High-Beta* (20-32 Hz) in order to highlight other patterns correlated with learner's motivation. We also plan to address a complementary study to understand distinctive physiological changes associated with varying difficulty levels of different missions.

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