Offering Multiple Mission Trials: A Physiological Study of Players' Motivational State

Lotfi Derbali and Claude Frasson

Département d'informatique et de recherche opérationnelle
Université de Montréal, C.P. 6128, Succ. Centre-ville Montréal, Québec, H3C 3J7 Canada

Abstract. Trials and attempts are common and are the means by which players upgrade their skills during gameplay. It is unclear whether or not high level of motivation holds when the gameplay is characterized by a high degree of repetitiveness. Assessing effects that these multiple trials may have on players' motivation is a crucial step in order to clarify how and to what extent a mission could be played. Thus, this study explores the effects of multiple mission trials on player'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. We used Keller's ARCS theoretical model of motivation and physiological sensors (heart rate, skin conductance and electroencephalogram) to record participants' reactions during interactions with different missions and across multiple trials. Results showed that physiological patterns and their evolution are objective tools to assess effects of multiple mission trials on players' motivation.

Keywords: Motivation, serious games, multiple trials, physiological sensors.

1. Introduction

Serious Games (SG) are computer applications that combine a serious intent, learning and training using video environment or computer simulation. They have a great potential to support immersive learning experiences and have become an important social trend. Furthermore, it is widely acknowledged that learners' psychological and cognitive states have an important role in intelligent systems and SG. For instance, engagement and motivation or disaffection and boredom obviously affect learners' wills and skills in acquiring new knowledge [1]. SG cannot therefore ignore these states and should take them into account during learning process. One of these states is motivation which plays a crucial role in both learners' performance and use of SG over time [2]. Motivation is generally defined as that which explains the direction and magnitude of behaviour, or in other words, it explains what goals people choose to pursue and how they pursue them [3]. Several studies have showed the importance of motivation and its role in improving learners' outcomes. A separate body of research within the study of motivation has focused on answering the question: "How to efficiently assess learners' motivation?". Most of the methodologies rely on questionnaires that try to convert subjective data (user opinion) into more objective data [4, 5].

Recent studies have involved a variety of electro-physiological sensors, such as heart rate (HR), skin conductance (SC) or electroencephalogram (EEG), to assess motivation and response to emotional and cognitive stimuli [6-10]. These sensors and many others provide more direct measures of learners' reactions than self-report method.

Moreover, several researches have shown that SG can provide a suitable context via interactive, engaging and immersive tasks [5, 11, 12]. They also indicate that missions of SG designed to maximize the players' interest should be challenging, task-specific, motivating and novel. This can help player avoid attending to a boring or repetitive task. Indeed, a lack of activities that are characterized by novelty is one of basic reasons of players' stagnation and ultimately, leads to lose their motivation [13]. However, most existing SG offer the opportunity of multiple mission trials (repetition) to players who possibility made mistakes and needed multiple attempts. From educational viewpoint, the more something is repeated, the more likely players are to remember (learn) it. In SG environment, repetition mission provides additional time to acquire knowledge, master certain skills or merely have fun. Thus, the potential of benefits of repetition must be weighed against the potential drawbacks. Repetition task or mission during gameplay is often reported by several studies, though the impact of this repetition on players' motivational state remains largely unexamined. Understanding the effects of multiple mission trials on player's motivational state is of particular significance for our research work. Potential findings aim to clarify how missions should be used and to what extent they are employed in order to avoid motivational problems. In this paper, we aim to carry out our study during players' interactions with our SG called HeapMotiv. Our experimental study combines psychometric instruments with physiological recordings, namely HR, SC and EEG. We ask the following research question: What are relevant physiological trends during multiple mission trials and how are they correlated with players' motivation?

The organization of this paper is as follows: in section 2, we present previous work related to our research. In section 3, we detail our experimental methodology, present HeapMotiv and explain our empirical approach in assessing players' motivation. In section 4, we present the obtained results and discuss them, in the last section, as well as present future work.

2. Related Work

For over 20 years now, several researchers have been using computer games as a platform for studying intrinsic motivation for learning. They have reported important factors responsible for the positive effect created by computer games such as challenge, curiosity, control and fantasy [5, 11, 14]. Performance, time spent in a game, response time, and physiological reactions are examples of various indicators that can be used to determine the close relationship between motivational factors and players' motivational state. Having tools to assess player's motivation, SG designers have focused on factors, situations and scenarios that make game motivational. They also use a variety of means to foster an emotional response in players. Narrative context, rules, goals, rewards, problem-based situations, multisensory cues, and interactivity have been used in order to achieve this [15-17]. Recently, SG researchers are not only interested to design games that combine serious intent, learning and training possibly by using video environments or computer simulations; but also emotionally-engaging games that take affective user states into account, integrate computational models of affect, emotions and context and employ currently available technology to promote emotive experiences [18-20]. Thus, assessing players' states is of particular importance in establishing proper strategies and understanding the processes that might explain differences between players' performance and motivation. Unlike human beings, intelligent systems and SG cannot exclusively rely on observational cues, such as posture and gesture, to infer emotional and cognitive states. Moreover, the effectiveness of any study regarding the assessment of players' states depends on the choice of proper assessment tools and the accuracy of the selected tools. Some researchers have used theoretical models of motivation and have proposed several rules to infer motivational states from players' interactions with SG [21, 22]. Recent studies have integrated physiological sensors in assessing the physiological effects of motivation in terms of peripheral nervous system activity expressed by changes in HR and SC, brainwaves through the use of EEG [7, 23, 24], etc.

3. Method

3.1 HeapMotiv

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 player has to play a mission before obtaining a sign direction. In its current version, HeapMotiv is comprised of three missions (*Heap-Tetris*, *Heap-Shoot* and *Heap-Sort*), each intended to entertain and educate players about some basic concepts of binary heap, general purpose properties and application to sort elements of an array (see Fig. 1). *Heap-Tetris* is based on traditional Tetris game where a player has to move nodes during their falling using the arrows to fill a binary tree without violating the heap property. *Heap-Shoot* is based on shooter games where a player has to spot violations of shape and heap properties and has then to fix these violations by shooting misplaced nodes. *Heap-Sort* illustrates a comparison-based sorting algorithm which 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.

3.2 Assessment of Learners' Motivation

The ARCS model of motivation [4] has been chosen to theoretically assess player's motivation. Indeed, Keller's ARCS model is of particular interest in our study since it has been used in learning, training and games [3]. Keller used existing research on motivational psychology to identify four categories of motivation: *Attention*, *Relevance*, *Confidence* and *Satisfaction*. In addition to the ARCS self-report, we have used objective measures that are not directly dependent on a player's perception. In our empirical approach, we used non-invasive physiological sensors: HR and SC. These sensors are typically used to study human affective states [25]. 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 [26]. More precisely, our EEG analysis relies on the attention ratio or *Theta/Beta1* which is widely used in neurobehavioral studies. According to [27], 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.

3.3 Procedure

Twenty participants (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. 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 participant's non-dominant hands, leaving the other free for the experimental task. An EEG cap was also conveniently fitted on participant's head and each sensor spot slightly filled with a proprietary saline solution. 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. Participants were asked to minimize eye blinks and muscle movements in order to reduce artifacts during recording. A 60s-baseline was also computed before the beginning of the game. The motivational measurement instrument called Instructional Materials Motivation Survey IMMS [4] was used following each mission to assess learners' motivation. Due to time constraints and in order to achieve minimum disruption to participants, we used a short IMMS form which contained 16 out of the 32 items after receiving the advice and approval from John Keller. Missions have been played by each participant as follows: *Heap-Tetris* (at most 3 trials), *Heap-Shoot* (at most 3 trials) and *Heap-Sort* (exactly 1 trial). The 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 *Beta1* (12-20 Hz) in order to compute the attention ratio (*Theta/Beta1*) as described above.

4. Results

Friedman's ANOVA by ranks tests showed that significant differences for the general motivational score as well as each category of the ARCS model were observed between missions, *except* for Relevance and Satisfaction categories (*Motivation overall* *score:* $F(1,2) = 11.52$, $p < .05$; *Attention:* $F(1,2) = 6.12$, $p < .05$; *Confidence:* $F(1,2) = 13.84$, $p < .05$). These results excluded the hypothesis that players' motivation remains roughly the same between mission periods. They opened up opportunities to answer our main research question by studying each mission in terms of general physiological trends during multiple mission trials.

Using self-reported ARCS scores following the mission, we have divided participants in two groups: a "Below" group representing participants who reported motivation scores below that of the overall average and an "Above" group presenting the opposite (scores above average). Table 1 shows charts of physiological data (Y-axis) throughout the 3 trials (X-axis) carried out for *Heap-Tetris* and *Heap-Shoot* missions. Each dot on the plane represents the group average for 5 seconds. Red or blue curved lines are order 3 polynomial trend lines that represent data fluctuations during time.

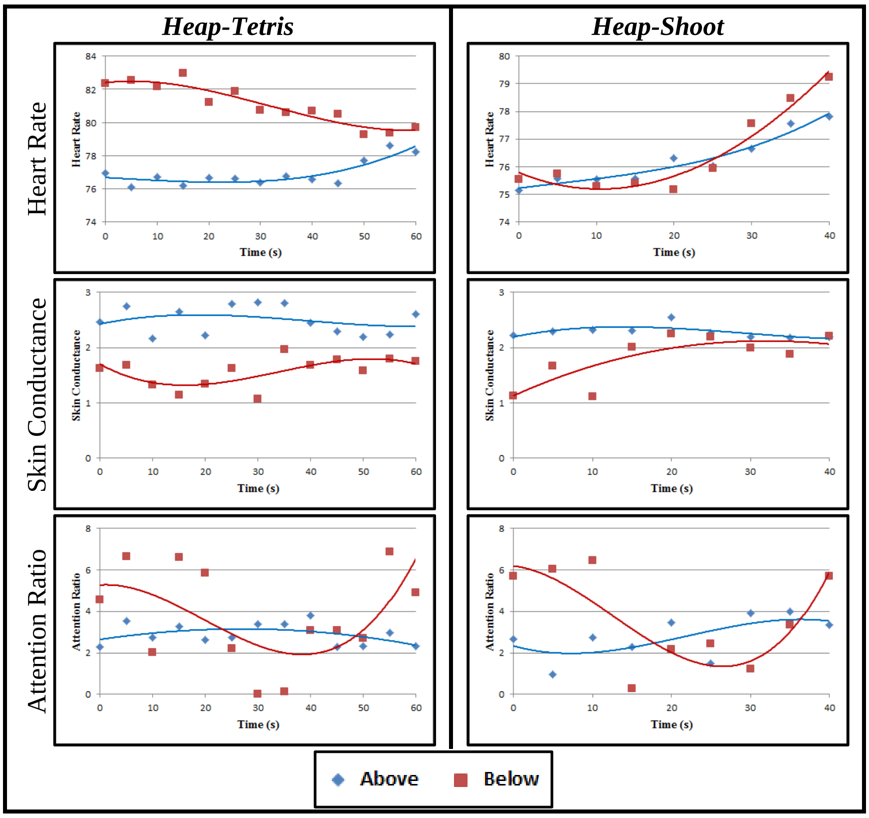

Table 1. Physiological data and trends across multiple trials

Even though no clear trends were found in SC and HR, participants of "Below" group have had a relatively large amount of fluctuation across trials. They have especially lost attention (increasing curve of EEG attention ratio) during the third trial (last 15 seconds for *Heap-Tetris* and last 10 seconds for *Heap-Shoot*). Furthermore, one may think that participants of "Above" group were those who have become more attention and have continually reduced their EEG attention ratio, but our findings seem to indicate that this is only partially true. Indeed, participants of "Above" group have not presented a decreasing curve during time, but have just maintained their attention in a steady way with a small amount of fluctuation across trials. Thus, "Above and "Below" groups can be differentiated by the amount of fluctuation in the physiological data or by how many bends (hills and valleys) appear in the curve.

We have also studied the third mission (*Heap-Sort*) which was only played once (exactly 1 trial) but it contains though repetitive tasks (insert and delete elements from a binary heap, verify and establish the heap properties after each insertion or deletion). As expected, small amounts of fluctuation have been found regarding HR and SC evolution during time (150 seconds) for both groups and regarding attention ratio for "Above" group. Surprisingly, however, the amount of fluctuation in attention ratio was weak, if not absent for "Below" group. Thus, we cannot rely on our first findings to differentiate between "Above" and "Below" groups during *Heap-Sort* mission. Additional interpretations are necessary to achieve this. For example, monitoring attention ratio with respect to the negative correlation between this ratio and players' attention level constitutes a way to distinguish between motivational states. In Table 2 (attention ratio chart), it is clear that the blue curve representing the "Above" group was below the red one representing the "Below" group.

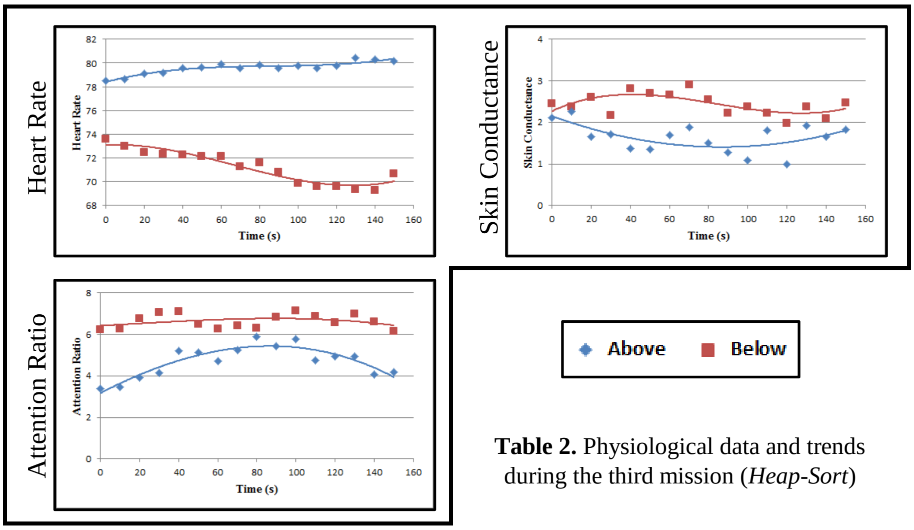

Table 2. Physiological data and trends during the third mission (*Heap-Sort*)

5. Conclusion and Future Work

We have assessed learners' motivation while achieving different missions of our serious game using the ARCS theoretical model as well as three objective physiological measures: HR, SC and EEG. Results have shown that offering multiple trials (*Heap-Tetris* and *Heap-Shoot* missions) has impacts on players' motivational state. A large amount of fluctuation, especially observable in the evolution of the EEG attention ratio, has characterized participants with low motivation; whereas motivated participants have a small amount of fluctuation across trials. This is also show the relevance and importance of adding the EEG in our empirical study, even more so when differentiation between "Above" and "Below" groups cannot be clearly established by the use of HR and SC alone. However, almost similar trends with different intensities have been found between the two groups during the last mission (*Heap-Sort*) which was only played once. We plan to address investigations of alternate physiological analysis, such as dimensional appraisal in terms of arousal and valence dimensions, in order to highlight other patterns correlated with players' motivational states. Moreover, different game elements, such as risks, errors, difficulty level, and familiarity, seem to be more relevantly correlated with players' motivation and attention. All of these issues will be addressed in future work.

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