

# Physiological Evaluation of Attention Getting Strategies during Serious Game Play

Lotfi Derbali, Claude Frasson

Département d'informatique et de recherche opérationnelle  
Université de Montréal, 2920 Chemin de la Tour, Montréal, CANADA

**Abstract.** This study investigated *Attention* getting strategies and their evaluation during serious game play. We proposed, therefore, the use of physical sensors, namely heart rate, skin conductance, and electroencephalogram (EEG), as well as a theoretical model of motivation (Keller's ARCS model) to evaluate two *Attention* getting strategies in a serious game environment. Results showed that some specific EEG ratios were more appropriate than others to physiologically evaluate learners' reactions. Finally, physiological evaluation of *Attention* getting strategies can relevantly provide an appropriate tool to discriminate between attentive and inattentive learners.

**Keywords:** *Attention* getting strategies, Keller's ARCS model of *Motivation*, physical sensors, EEG ratios.

## 1 Introduction

It is widely acknowledged that psychological and cognitive learners' states can affect their wills and skills in acquiring new knowledge [1]. Intelligent systems cannot, therefore, ignore the learners' states and should take them into account during learning process. One important learners' state is *Motivation* which plays a crucial role in both learners' performance and use of intelligent systems over time [2]. *Motivation* is considered a natural part of any learning process and learners need to believe that the activity will bring about some gains or sense of satisfaction [1]. Several studies have been undertaken to measure motivational learners' states. Self-report questionnaires have been the most frequently used method to assess *Motivation*. In addition, recent studies have involved a variety of physical sensors, such as camera, skin conductance (SC) or electroencephalogram (EEG), to measure *Motivation* and response to emotional and cognitive stimuli [3]. However, there are a handful of studies that have considered motivational strategies to overcome motivation problems in computer-based education context.

The present paper aims to examine the implication of different physiological sensors to evaluate *Attention* getting strategies, the first dimension of motivational strategies as defined by Keller's ARCS model of *Motivation*, and to highlight the corresponding learners' patterns. Since the serious games have been supposed an engaged environment that includes several *Attention* getting strategies [4], we use a serious game to carry out our empirical study. We also use three physiological recordings, namely heart rate (HR), skin conductance (SC) and brainwaves (EEG).

## 2 Procedure

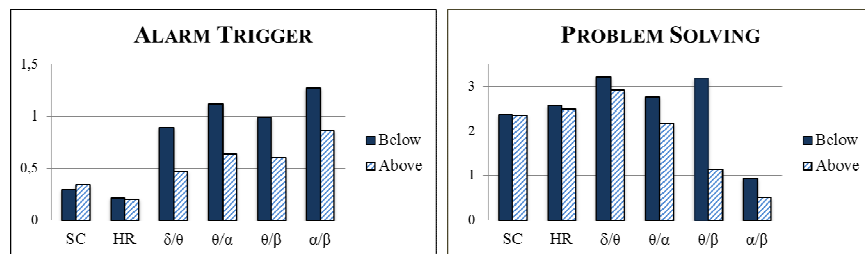
The ARCS model of *Motivation* [5] has been chosen to theoretically assess motivational strategies used in a serious game. Keller used existing research on motivational psychology to identify four categories to constitute the ARCS model of motivation: Attention, Relevance, Confidence, and Satisfaction. Each of the four categories also has subcategories that are useful in diagnosing learners' motivational profiles and in creating motivational tactics (or strategies) that are appropriate for the specific problems that are identified. Our approach attempts to determine the close relationship between *Attention* getting strategies and their physiological effects on learners. It starts by identifying some significant *Attention* getting strategies that are drawn from the ARCS theoretical model and evaluating their impact on learners using the physiological measures. Besides the SC and HR sensors which are typically used to study human affective states [6], we have considered relevant to use the EEG sensor in our proposed approach. EEG ratios of the different frequency bands were computed for delta/theta ( $\delta/\theta$ ), theta/alpha ( $\theta/\alpha$ ), theta/low-beta ( $\theta/\beta$ ) and alpha/low-beta ( $\alpha/\beta$ ).

Twenty-nine subjects (11 female), with mean age of  $26.7 \pm 4.1$  years, were invited to play a serious game called FoodForce. Virtual tutors also accompany the player throughout the missions by offering various tips and lessons. A pre-test and post-test were also administered to compare learners' knowledge acquisition regarding the content of the serious game. The motivational measurement instrument called IMMS was used following each mission to assess *Motivation*. The SC and HR sensors were attached to the fingers of subjects' non-dominant hands, leaving the other free for the experimental task. EEG was recorded by using a cap with a linked-mastoid reference. Three selected areas (F3, C3, and Pz) were placed according to the international 10-20 system; the reference and the ground sensors were located at Cz and Fpz respectively. The EEG was sampled at a rate of 256 Hz. A Power Spectral Density (PSD) was computed to divide the EEG raw signal into the EEG ratios ( $\delta/\theta$ ,  $\theta/\alpha$ ,  $\theta/\beta$ , and  $\alpha/\beta$ ).

## 3 Results

Subjects have been separated into two groups according to the ARCS scores after each mission: those with scores below the overall average (group "Below") and those with scores above the overall average (group "Above"). According to Keller's model, *Problem Solving* and *Alarm Trigger* are two *Attention* getting strategies. To evaluate *Problem Solving* strategy used for example by the virtual companion in the fifth mission of the serious game, we have considered the *Attention* scores related to this mission in order to determinate the "Below" and "Above" groups of subjects and compare their physiological reactions. The same procedure has been applied for the *Alarm Trigger* strategy. The physiological reactions for *Alarm Trigger* and *Problem Solving* strategies between the two groups are presented in Figure 1.

General results showed that SC and HR reach their limits in some cases for evaluating learners' reactions. In fact, no clear trends were found in SC and HR for evaluating *Attention* getting strategies (*Problem Solving* and *Alarm Trigger*). Conversely, EEG ratios, especially  $\theta/\beta$  and  $\alpha/\beta$ , have showed different trends for these strategies. They tended to decrease for subjects of "Above" group whereas they have shown opposite trends for those of "Below" group. They can provide an objective evaluation of motivational strategies for distinguishing between learners' reactions.



**Figure 1.** Example of physiological reactions (two Attention getting strategies)

An explanation of these different trends between the two groups can be given by neuroscience. For example, a negative correlation exists between the  $\theta/\beta$  ratio and the attention level of adults [7]. Furthermore, the ratio of  $\alpha/\beta$  waves has been used as an indication of relaxation and better concentration and relaxed learners' states are indicated by increased  $\beta$ ; decreased  $\alpha$ ; so decreased  $\alpha/\beta$  ratio.

## 4 Conclusion

In this paper, we have assessed the effects of the first dimension of motivational strategies, namely *Attention* getting strategies, in a serious game using the ARCS theoretical model as well as three physiological sensors: HR, SC and EEG. We have successfully identified physiological patterns, especially EEG  $\theta/\beta$  and  $\alpha/\beta$  ratios, to evaluate these strategies and to possibly distinguish between attentive and inattentive learners. The integration of these results into an intelligent tutoring system, for example, can enrich the learner model and adapt the motivational interventions of the tutor model.

## Acknowledgments

We thank the CRSNG, the FQRSC and the Tunisian Government for their support.

## References

1. Bandura, A.: Social foundations of thought and action: A social cognitive theory. Prentice-Hall (1986)
2. de Vicente, A., Pain, H.: Informing the detection of the students' motivational state: an empirical study. ITS'02, pp. 933-943, Berlin, Heidelberg (2002)
3. Derbali, L., Frasson, C.: Prediction of Players Motivational States Using Electrophysiological Measures during Serious Game Play. ICALT'10, pp. 498-502 (2010)
4. Prensky, M.: Digital Game-Based Learning. New York: McGraw Hill (2001)
5. Keller, J.M.: Motivational design for learning and performance: The ARCS model approach. Springer, New York (2010)
6. Lin, T., Imamiya, A., Hu, W., Omata, M.: Display Characteristics Affect Users' Emotional Arousal in 3D Games. Universal Access in Ambient Intelligence Environments (2007)
7. Putman, P., van Peer, J., Maimari, I., van der Werff, S.: EEG theta/beta ratio in relation to fear-modulated response-inhibition, attentional control, and affective traits. Biological Psychology 83, 73-78 (2010)