# A Preliminary Study on Learners' Physiological Measurements in Educational Hypermedia

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***Abstract*— This paper presents the findings of a preliminary study about the use of bio-feedback sensors in the context of an educational hypermedia environment; skin conductance, blood volume pulse and heart rate physiological data were gathered. The aim of the study was to examine learners' emotional arousal variability, and possible correlations of the physiological data with other psychological constructs such as trait and self-reported anxiety. Ten university students participated in two identical experiments, with a mixed between-within experimental design (20 samples). According to the findings, heart rate was significantly correlated with trait and self-reported state anxiety (in the second experiment), but not with academic performance in an on-line exam. Skin conductance and blood volume pulse had only marginal variations, perhaps due to the absence of intense stimuli.**

**Keywords: Affective computing, physiological sensors, e-learning, emotional arousal**

## I. INTRODUCTION

The emotional state of a user at any given moment is susceptible to constant variations due to factors that are either triggered within a specific environment or may as well be extraneous and unrelated to human-computer interactions. As a result, users may experience a wide range of emotions while interacting with hypermedia content, both positive and negative. In parallel, research on emotions has shown that the association of certain emotions to specific events may have a significant impact on information processing and/or on the consolidation of newly acquired information [1, 2, 3]. The role of emotions is also been discussed specifically in relation to human-computer interaction, with constantly increasing research interest [4, 5].

Hence, the monitoring and identification of users' emotional state while interacting with hypermedia content could be useful, since it would allow the employment of corresponding personalization techniques in order to reduce the influence of negative emotions. However, identifying human emotions with high accuracy is a complex procedure, whereas altering the emotional state of a user is even more challenging.

Our research is generally focused on web-based learning, information processing, and personalization. Learners' individual differences are represented by a multi-dimensional user model, which also includes the notion of emotional processing [6]. This term refers to a combination of regulatory and affective factors, with anxiety as the core element of this construct. Thus, in terms of identifying learners' emotions, we are mainly interested in the different forms of anxiety (state and trait anxiety [7], cognitive test anxiety [8], computer anxiety [9]), and its manifestations as an increase of stress and negative emotional arousal with consequent negative effects on learning performance [10].

The use of questionnaires in user profiling procedures is a valid form of measurement regarding learners' predispositions towards developing high levels of anxiety in a web-based learning environment, at least as shown by our previous research findings. Nevertheless, the variability of learners' emotional state remains evasive, whereas the notion of a system that dynamically adapts on individuals' fluctuating emotional state cannot be realized.

Therefore, a real-time method of profiling was introduced, involving the use of biometric sensors providing measurements of skin conductance, heart rate, and blood volume pulse, in an effort to capture users' state-like emotional characteristic in a more accurate way. This paper presents the initial findings regarding the use of biometric sensors, exploring possible interactions and correlations with questionnaires and learners' academic performance.

## II. THEORETICAL BACKGROUND

Within the context of research studies on emotion and human-computer interaction, corresponding systems have been developed for identifying users' emotional state with the use of biometric sensors. The most commonly used sensors are those measuring galvanic skin response (also referred as skin conductance or electrodermal activity), heart rate, and blood volume pulse. In our study, we have used all these three physiological measurements, as in the following previous studies.

Ward and Marsden [11] have examined users' physiological responses to different web-pages. The sensors that were used provided measurements of skin conductance, heart rate, and blood volume pulse. According to their findings, during periods of inactivity heart rate and skin conductance are reduced, while blood volume pulse tends to increase. During performing simple tasks, there is only a small variability in all three measurements, indicating low

levels of emotional arousal. Unexpected events, however, triggered intense variations (increase of heart rate and skin conductance, decrease of blood volume pulse), as a result of higher emotional arousal.

In another study [12], the physiological measurements were mapped on the circumplex model of emotion, which consists of two dimensions on which every single emotion can be defined: valence (pleasure-displeasure) and arousal (degree of intensity) [13]. The physiological variables were skin conductance, skin conductance level, skin conductance responses, heart rate, and heart rate variability. This study supports that heart rate is indicative of valence, while skin conductance is related to arousal.

Electrodermal activity, facial electromyography and heart rate were the physiological variables in a study that involved the presentation of two versions of a computer-based simulated mobile environment to users [14]. These two versions were designed in a way that each would evoke different emotional responses; correlations between arousal, valence, and the physiological measurements were found.

A rather different approach involved the integration of electromechanical film sensors in a chair, in order to measure variations in heart rate [15]. According to the findings of this study, the physiological responses were correlated with the emotional valence (positive, neutral, and negative) of the stimuli that were presented to users.

Biometric sensors were also used in an online communication system [16], using galvanic skin response and blood volume pulse sensors. In this study, it was also supported that galvanic skin responses are indicative of arousal, while blood volume pulse is related to valence; the latter however was considered as very difficult to measure in an accurate way.

Our specific aim was to investigate how such physiological measurements are related to anxiety and the regulatory dimension of our user profiling model , as measured by "traditional" measurements (such as questionnaires and self-report). Thus, our research questions may be formed as follows:

- Are the physiological measurements of skin conductance, heart rate, and blood volume pulse, monitored within a web-based educational environment, related to individuals' trait anxiety?
- Are these physiological measurements related to individuals' regulatory emotional mechanisms and their self-reported levels of state anxiety?
- Is learners' academic performance affected by the levels of emotional arousal within an e-learning environment?

## III. METHOD

### A. Procedure

The design of the study was a mixed between-within subjects design. The number of participants was 10 (6 female and 4 male), and they were all students at the Department of Computer Science of the University of Cyprus. Two identical experiments with the same participants took place in a computer lab, with a 5 day interval, providing a total of 20 samples.

Each participant was asked to log into the system and to firstly fill in the psychometric questionnaires of anxiety and emotional regulation. Thereupon, the sensors were placed on the participant, who was subsequently asked to navigate in an e-learning course about HCI design

.The participants were aware that an exam would follow, in order for a certain degree of emotional arousal to be evoked; the sensors provided real-time measurements throughout the learning procedure, while there were not any time constraints imposed on learners. Additionally, users were able to report their self-perceived levels of anxiety every five minutes.

The participants, after the completion of the learning course, took an exam on the subject that they were taught, with their scores indicating their academic performance in terms of efficient information processing and consolidation of the newly acquired information.

### B. Materials

*Bio-feedback system*: TTL T7400C ProComp2 with v5.0 Infiniti Software (Thought Technology).
*Skin conductance*: TTL SA9309M Skin Conductance Sensor.
*Heart rate and blood volume pulse*: TTL SA9308M Heart Rate/BVP Sensor.
*Anxiety*: Spielberger's Manual for the State-Trait Anxiety Inventory (STAI) [7]. It should be mentioned that only the trait anxiety scale was used.
*Emotional Regulation*: We used a questionnaire that was developed by us, and includes items derived from emotional intelligence [17], self-regulation [18], and self-efficacy [19] tests; Cronbach's α that indicates reliability reaches 0.718.
*Self-reported state anxiety*: Self-reported measure of state anxiety taken in time slots of 5 minutes. An "anxiety bar" is presented on screen, and users position themselves on a 1-10 scale.
*Exam*: Twelve multiple choice questions on HCI related issues that were previously taught in the e-learning course.

## IV. RESULTS

According to the findings of the first experiment, there is a statistically significant positive correlation between learners' mean heart rate and their levels of trait anxiety (STAI questionnaire): Pearson's $r=0.668$, $p=0.035$. However, neither high levels of trait anxiety nor elevated heart rate were correlated with academic performance. There was also a negative correlation between self-reported levels of anxiety and emotional regulation ability, though not reaching statistical significance ($r=-0.565$, $p=0.089$). As it concerns skin conductance and blood volume pulse, there was only a marginal variability without any correlations to academic performance, trait anxiety, or emotional regulation.

The second experiment confirmed the relation between heart rate and trait anxiety ($r=0.640$, $p=0.046$). Additionally, heart rate was positively correlated with learners' self reported anxiety ($r=0.739$, $p=0.015$), possibly due to the fact that users had become more familiar with the environment and the self-report procedure. The negative correlation between self-reported levels of anxiety and emotional

regulation was also observed, though still not reaching statistical significance (r=0.610, p=0.61). Skin conductivity and blood volume pulse measurements did not provide any useful data in terms of variability or correlations. Academic performance was also unrelated to any other variable. As expected, learners' scores in the second experiment were higher, due to their previous learning experience (the mean rose from 71% to 85%, paired samples t=3.157, p=0.012). All the other variables were basically unaffected. Thus, it seems that previous experience certainly has a positive effect on information consolidation, but not on anxiety levels that seem to be essentially related to trait-like characteristics.

## V. DISCUSSION

The experiments that were described above provided initial results on the use of bio-feedback sensors within the context of educational hypermedia environments. Even though this preliminary research does not allow the formation of definitive conclusions, the main finding is that an e-learning course does not evoke significant levels of emotional arousal that would manifest in the form of physiological responses. On the contrary, preexisting higher levels of trait anxiety are related to an increase in heart rate, while both seem independent from academic performance; this may be explained by the fact that a certain amount of anxiety is rather beneficial in learning as a motivational factor.

In any case, heart rate seemed to be the most informative physiological measurement, whereas it was correlated with self-reported state anxiety in the second experiment- perhaps because an increased heart rate can be self-perceived while skin conductance and blood volume pulse probably remain elusive to the individual. Nevertheless, skin conductance and blood volume pulse could provide useful data in more stressful situations, especially in the case of intense stimuli or unexpected events, as shown in the Ward and Marsden study [11]; our findings are generally in line with the conclusions of the latter study.

It should however be mentioned that the small sample size is a basic limitation of our study, inhibiting thorough statistical analyses and generalization of the findings. Also, there were only two questionnaires used in the profiling procedure; constructs such as computer anxiety and cognitive test anxiety were not taken into account. It could additionally be supported that the on-line course and the exam procedure were not designed in a way that would bias users towards emotional arousal, but on the other hand this was not the purpose of the study.

Correspondingly, the next step of our research regarding bio-feedback and learning would be the design of a larger scale study, with a far more elaborate methodology, involving positive and negative stimuli in an educational environment. This would allow a better identification of learners' emotional state in web-based learning environments and perhaps, in the future, the proper manipulation of a learning course in order to positively affect learners' levels of emotional arousal and valence.

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