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TITLE:

A VR-based Serious Game for Studying Emotional Regulation in Adolescents

ABSTRACT:

We all use more or less adapted strategies to confront adverse emotional situations in our lives without being psychologically affected. Emotional Regulation (ER) strategies that we use determine the way in which we feel, express and behave. Moreover, ER strategies are particularly important in adolescents, a population in the age when the deficits of ER strategies can be linked to the appearance of numerous mental health disorders such as depression or anxiety, or disruptive behaviors. Thus, the early detection of dysfunctional ER strategies and the training in adaptive ER strategies will help us to prevent the future occurrence of possible behavioral and psychosocial disorders. In this paper, we present the GAMETEEN SYSTEM (GT-System), a novel instrument based on Virtual Reality and serious games for the assessment and training of ER strategies in adolescent population. The results of our preliminary evaluation suggest that this system is effective in training and evaluating emotional regulation strategies in the adolescent population.

KEYWORDS---Serious Games, Virtual Reality, Emotional Regulation, Unity3D, ECG

Introduction

Emotional Regulation (ER) strategies determine the way in which we feel, express and regulate our emotions [1]. Every day there is more research emphasizing the role that these ER strategies play in the development and maintenance of adaptive and healthy behavior. Adaptive ER strategies are especially important during adolescence, when its deficit are becoming evident and might be an origin of many psychosocial and behavioral problems. Indeed, there is a great social concern for the increase in psychological disorders as well as disruptive behavior and increase in bullying in the classrooms. Therefore, a current challenge corresponds to prevention of numerous emotional and behavioral problems through the early detection of dysfunctional ER strategies and training in adaptive ER strategies.

We believe that the use of innovative technologies can help to give society a new tool to prevent psychological and behavioral disorders in adolescent's population. Toward that end, we designed and developed the GameTeen System (GT-System), an interactive Virtual Reality (VR) Serious Game (SG) based system for training and evaluation of ER strategies.

ER Assessment in the 21st Century

Currently, ER assessment instruments are based on subjective questionnaires that ask patients about the way in which they experience and manage their emotions. Another evaluation method is the use of laboratory tests in which patients are asked to carry out tasks that generate emotions, or these emotions are induced, in order to subsequently assess the strategies they use to regulate them.

Objectivizing the ER Instruments

One of the limitations of the traditional instruments for ER assessment is the lack of objectiveness of their results. Indeed, the results collected come from the subjective responses of patients to a series of questions related to their emotions and the way how they handle these emotions. This drawback could be solved by using more adequate techniques which provide more objective results, such as physiological signals.

Therefore, in the design of the GT-system we aimed to address this particular limitation. The GT-system allows the real time monitoring and registration of psychological and physiological parameters, such as wireless electrocardiogram (ECG); and emotional state evaluation; useful for the assessment of the applied ER strategies.

Increasing Engagement in the ER studies

Although traditional instruments (i.e., questionnaires) have proved to be useful in clinical psychology field, they present the following limitations: repetitive, boring, and unattractive for adolescents, population who is especially reluctant to be assessed. We believe that with the development of instruments based on SG, and the great capacity for immersion and persuasion of new technologies such as VR, we can make the evaluation and intervention process much more attractive and motivational. Indeed, researchers have already showed the effectiveness of SG in different fields such as treatment of anxiety and attention disorders [2] The Playmancer project [3] is an interesting example of system that uses multimodal recognition of emotions, in combination of SG for the training of ER strategies, in general population.

GT- System

The GT-System is an interactive Virtual Reality Serious Game - based system that allows training and evaluation of skills to tolerate and/or cope with unwanted emotions through the use of ER strategies. This system was designed according to intervention program principles, which consider that ER is a process that requires prior affective differentiation. In other words, in order to control the emotional experience, it is necessary to have the ability to recognize internal emotional states and to know differentiating them. Accordingly, it is necessary to assess the ER strategies used by each patient in order to detect deficiencies on which the intervention can focus.

Therefore, to comply with the intervention program, two steps can be differentiated in the GT-System:

- **Frustration Induction Game*:*** an induction phase where the GT-System induces a negative emotion of frustration.
- **Training phase of ER strategies**: training phase where adaptive ER strategies can be trained.

Frustration Induction Game

The Frustration Induction Game is a new version of classical "whack a mole" game. The game is located in a rural land scene with several holes, in which several moles can appear in a continuous way while playing the game (**Figure1**a).

The purpose of the game is to whack all moles with the help of a virtual mace that is hold by a customized semi-transparent avatar controlled by the participant with the mouse. The game has three levels of difficulty which are related to the velocity and frequency of appearance. During three minutes of the game, the patients have to hit correctly the maximum possible number of moles, thus obtaining maximum score (Precise Hit=15 points, Wrong Hit= -10 points). Finally, the score is published in the GameTeen web where the patients can check their score and compare their placing in a ranking, also accessible to the therapists.

The induction of frustration is achieved in the patients because the game was designed in a way that some hits are intentionally caused to be inaccurate. When a mole appears the system automatically assigns it a random value which is compared with the threshold value of the level. When the number is lower than the threshold value, the mole can escape. Therefore, the likelihood that a mole can escape unharmed, even if the participant's action was accurate, is 40% for level 1; 50% for level 2; and 65% for level 3.

Figure 1. Frustration Induction Game. The game is located in a rural land scene with several holes, in which moles can appear in a continuous way while playing the game (a). The scene changes to reddish flash because a mole has escaped (b).

Also, in order to increase the frustration induction, several tools of negative reinforcement are used. These tools correspond to mocking sound and reddish flashes (**Figure1**b), which appear when a mole escapes, during a short period of time. In addition, the game displays negative messages, such as “You won’t make it”, every 30 seconds.

Training Phase of ER strategies

Two mini-games were developed for the training phase of ER strategies: the respiration and attention strategy game.

The respiration strategy game consists of a feather (**Figure2**a and **Figure 2b**), which goes up, and down nine times, on the screen. When the respiration strategy game is chosen, users have to breathe in and breathe out at the same rate as the feather goes up and down. This ER strategy lasts 45 seconds and the duration of the feather’s movements is constant (2.5 seconds each one).

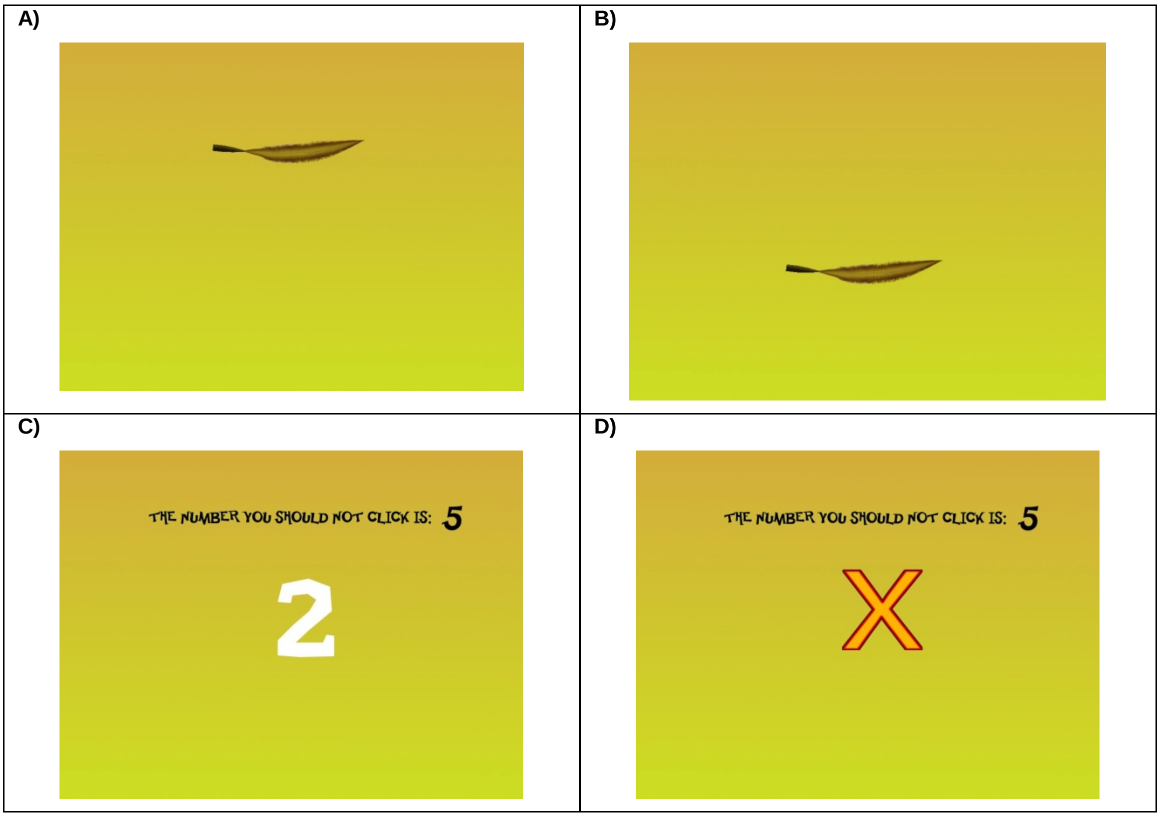

Figure 2. Training Phase of ER Strategies: (a and b) the respiration strategy game; and (c and d) the attention strategy game.

The attention strategy game consists of a number sequence (**Figure2**c and **Figure2**d) that appears on the screen. The users have to click the mouse over the number only when the number that appears is different from the number indicated in the instructions. The number is shown on the screen during 0.8 seconds, then this number disappears and is replaced by an X that is shown during 0.7 seconds, then another random number appears, and so on. For example, in the Figure2c, the participants have to click while the number is on the screen, before the X (Figure2d) appears and provided that the shown number is not 5.

GT-System Technologically Speaking

GT-System integrates a player's and a therapist's version. A wireless ECG is connected with the therapist PC through Bluetooth wireless connection. GT-System was programmed in C#, a friendly programming language that has many communication devices and web services libraries, using Unity3D as the development environment. Unity3D is a cross-platform game engine with a built-in IDE developed by Unity Technologies, used to develop video games for web plugins, desktop platforms, consoles, and mobile devices.

Player's and Therapist's Applications

The first version of GT-System was developed (for both player's and therapist's version) to be played using mouse and keyboard. The player's version is the application where the patients can play and be train their skills in ER strategies. The therapist's version is the application where the therapist can see the progress of each patient. In addition, both applications can monitor the recorded ECG signal and an estimated value of patient's heart rate in real-time (**Figure3**).

In order to allow the therapist to observe what the patient see in his/her screen, we designed a communication based on a client/server architecture where the therapeutic application works as server and creates the game which the player's application has to join. Then, when the game is started, the player's application sends remote procedure calls (RPC) with events, positions, and orientations, allowing the therapist's application to see the player's application screen.

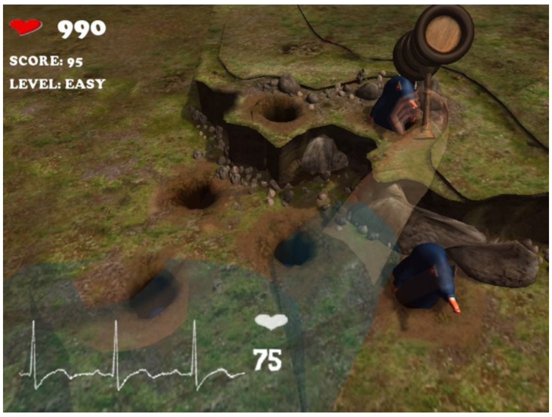

Figure 3. Therapist's application where the therapist can see in real time the patient playing the games, monitor the ECG signal and an estimated value of Heart Rate.

Regarding the physiological monitoring, the wireless ECG platform is connected to the PC via Bluetooth trough the serial port. Unity3D can read ECG values by using library "System.IO.Ports". This process is controlled by the therapist's application, which enables the serial port communication, reads the received data, and transfers theses values in a CSV file. In addition, ECG signal is also plotted in the therapist's application as shown in Figure3, in order to check the correctness of communication and to evaluate both the ECG's changes related to the emotions and ER strategies applied during the games, all in real time. Due to the fact that Unity3D do not have appropriate tools for plotting the ECG signal, we developed a small program in OpenGL, which links two points with a line in 2d coordinates, using the function glVertex. Finally, the therapist's application also has an algorithm that estimates the heart rate of the patient through the received values, and shows it on the screen.

Modeling of the Virtual Components

The GT-System provides an evaluation and training of ER strategies for adolescents. For this reason, all virtual components were designed for this target population. The virtual components that were modeled by our team were the following: a mole, an avatar, a mace and a rural land (**Figure4**).

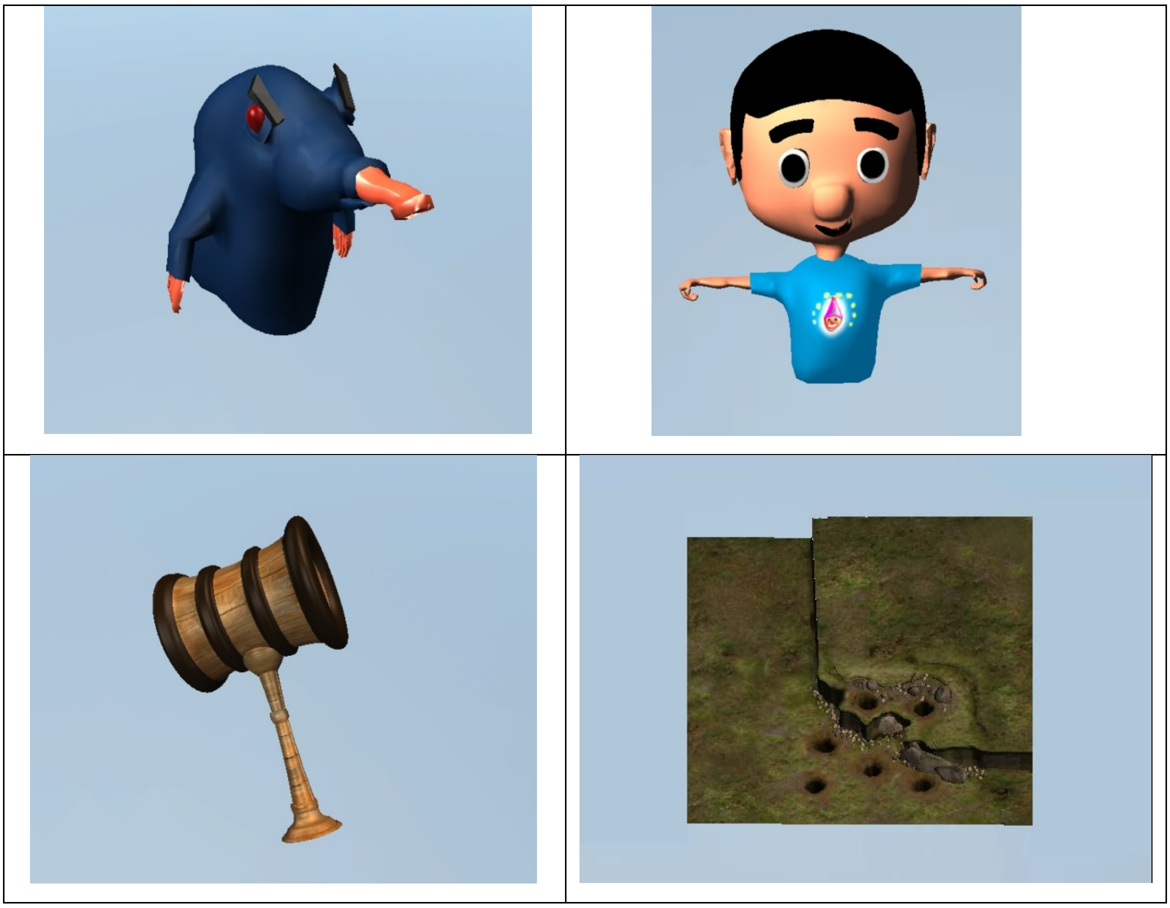

Figure 4. Models of (a) a mole, (b) an avatar, (c) a mace, and (d) the rural land. The target population (adolescents) were taken into account in the design.

Regarding the viewpoint of the game, the virtual camera was put behind the neck of the avatar, with 45 degree downwards tilt. Because the avatar has to be moved in order to reach all holes, we designed a system that allows the avatar to be moved according to the mouse's movements. This system consists on putting a transparent and flat surface perpendicular to viewpoint on the hip of the avatar, which covers all the field of view. An invisible line connects the center of the viewpoint with the mouse cursor (also invisible). In this way, the intersecting point between this line and the flat surface will be the point where the avatar will whack.

Finally, regarding the avatar's movements a biped skeleton, whose geometry of bones can be correctly modified in accordance with the whack's action, using an inverse kinematics (IK) algorithm, which allows articulating the arm. The movement of the arm corresponds to the mouse pointer movement. The reference point of the mouse pointer is placed of the skeleton wrist.

Virtual components and their animations were created by our team in Autodesk 3ds Max, exported in FBX format and directly loaded through Unity3D.

GT-System description

Figure5 shows a brief graphic that summarizes the logic of the GT-System

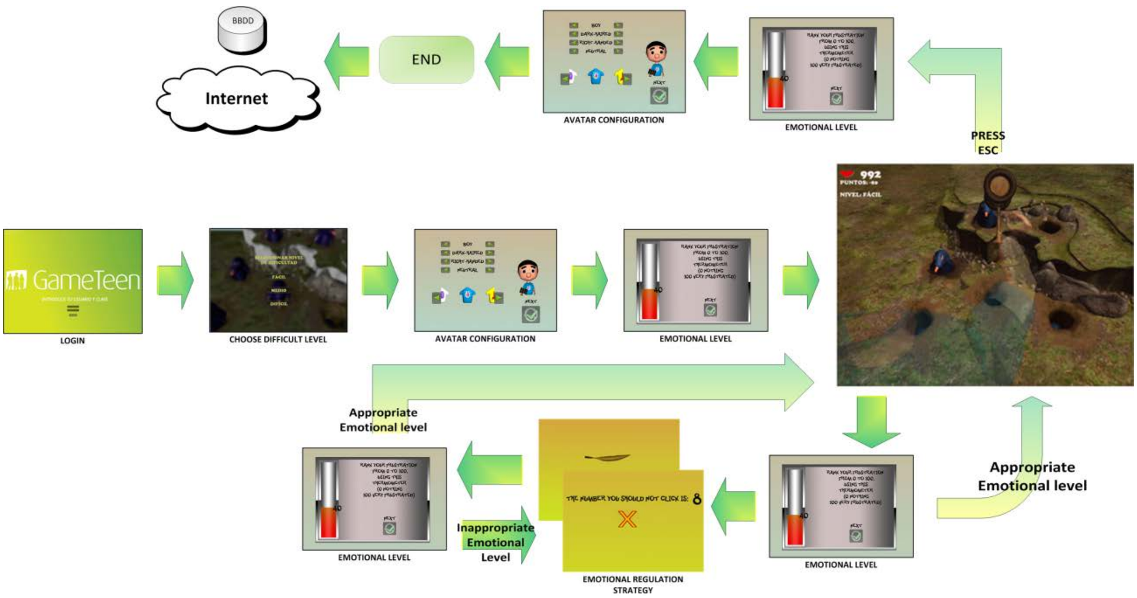

Figure 5. A GT-system logic schema. There are three overall phases of operation: initialization (middle row), training alternating between frustration induction and emotional response training (bottom row), and final assessment (top row).

In order to use the GT-System a user name and password have to be created, through GameTeen Web (**Figure6**). In order to obtain the user name and a password the patient have to complete a form with personal information, such as name, surname, age, city, sex, mail and nickname, which will be used for subsequent analysis.

Figure 6. GameTeen Web with (a) a registration screen; and (b) a ranking list screen.

After authentication phase the patients proceed to the selection screen where they can choose the initial difficulty level and personalize their avatar (i.e., chose gender, color hair, clothes, and initial emotional expression) that represents them in the game. The personalization of the avatar allows providing additional information for the therapists about initial mood of the patients and its evolution during the use of the system

After this step, the patients are asked to indicate their emotional level (frustration) using a thermometer, on a scale from 0 to 100. This data is saved as baseline frustration level. Then, the frustration induction game begins. During the game, the patients are asked to rate their frustration level every 3 minutes and the answer is compared with their baseline level. If the frustration level is lower or equal to the baseline level, in order to ensure that they are adequately regulating their emotions related to frustration. However, the patient needs to repeat the game maximum three times in order to check if their capacity to regulate frustration is stable. If the frustration level is higher or equal to baseline frustration level, the patients need to go to training phase of ER strategies. When the ER training ends, the frustration level is registered and compared again with the previous level. The frustration level value is updated each time in the system in order to obtain a valid comparison. If the frustration level decreased, the participant will play the frustration induction game. On the other hand, if the frustration level increased or was maintained, the patients go back to the training phase of ER strategies (three times maximum).

It should be noted that the game can be stopped at any time, when the patients decide by pressing *Esc* button on the keyboard. The game session ends with a final assessment of the frustration level (measured with a thermometer) and the final personalization of the avatar. All the data are saved in the database with a call to a web service developed for the GT-System.

GT- Evaluation

We evaluated the GT-System in order to obtain user feedback in a real context of use. Due to ethical issues, the system was validated with a non-clinical population (i.e., adolescents not diagnosed of any psychological and behavioral disorder).

Participants

51 adolescents participated in this study (28 boys); aged between 9 and 14 years (M= 11.23 years old; SD=1.42). Contact with the participants was established through the Summer School of the Universitat Politècnica de València. All parents of adolescents gave their informed consent prior to the inclusion in the study of their children.

Instruments

We used two types of instruments (psychological and physiological measures) to evaluate the participant's experience during the use of the GT-System:

- The Difficulties in Emotion Regulation Scale (DERS) Questionnaire measures (on a 5-point scale) the degree to which each participant is able to apply ER strategies in an emotional situation before the session. Higher answers indicate more difficulties with ER.
- Thermometers measure frustration level (on a 100-point scale) felt by each participants before, during, and after the game session.
- R-TIPS [4] is an electronic platform that was designed to capture the ECG signal of the participant in real time (**Figure7**). It incorporated Bluetooth synchronization with the therapist's application which sends the detected ECG signal to therapist's application. This wireless device allowed the participants to have more freedom of movements.

Figure 7. Illustration of R-TIPS. This platform allows monitoring of the cardiac signal wirelessly. It is composed by transmitter system and three sensors (see a).The transmitter system are placed in the participant's hip and the sensors are placed, one in the below right breast, other in the right side and the last in the back (see b).

ECG Analysis

In order to obtain precise results, the ECG recordings were analyzed off-line using customs software written in Matlab R2011b (MathWorks, Inc). We processed and cleaned up the ECG signal from all possible artifacts for each adolescent and we calculated the exact heart rate (HR). HR corresponds to heart beats per minute (bpm) for each moment of the game session.

Experimental Design

The experiment was conducted in individual sessions in the laboratory with duration of approximately of 45 minutes. The steps were the following

1. The adolescents completed DERS
2. The adolescents were trained in the use of the system
3. R-TIPS devices was set-up and synchronized with the therapist's PC.
4. Baseline phase for the cardiac signal analysis (the adolescents look on a black screen during 3 minutes) while we recorded a baseline for the cardiac signal analysis.
5. The beginning of the game session

Results

We performed all the statistical analyses with SPSS 17.0 (IBM's predictive-analytics software), with an alpha level of 0.05. The results indicate that GT-System seems to achieve the desired expectations, making it an effective tool to evaluate and train ER strategies.

Questionnaire Analyses

The analysis of the effectiveness of the frustration induction game, obtained with the thermometers, show that the frustration induction game was able to increase significantly[1] the frustration level between the beginning of the game at the end of the game (**Figure8**)

The analysis of regulation strategy effectiveness showed that 72.5% of participants reduced their levels of frustration after they applied the regulation strategy. These results showed that regulation strategy was able to regulate the frustration on the adolescents.

[1] $p<0.001$

DERS questionnaire analysis confirms the results obtained with the thermometers. With the DERS scale, we divided the adolescents in two groups. One group consisted of participants who scored high on the DERS scale (10 participants), who had a high difficulty to regulate their emotions (H-DERS). The second group consisted of participants who scored low on the DERS scale (13 participants), who had a low difficulty to regulate their emotions (L-DERS). The rest of participants were not considered because they had a normal level of ER capability.

Significantly[2] higher frustration levels appeared in the H-DERS group when compared with the L-DERS group (**Figure8**) after the frustration induction game. The results suggest that emotional induction was effective, and was even more effective for the participants who had more difficulty to regulate their emotions. On the other hand, no significant differences between the H-DERS group and the L-DERS group were observed after the respiration strategy, and attention strategy games. Thus, the Training Phase of ER Strategies helped to regulate the frustration level of all participants, independently of their previous DERS score.

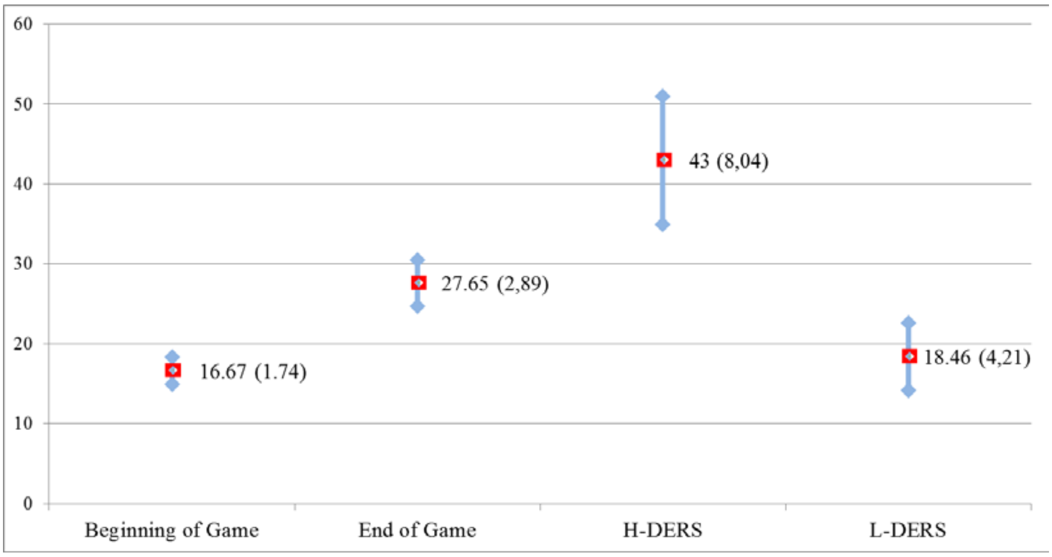

Figure 8. Mean values of frustration level from the thermometers of participants at the beginning of game, and at the end of game phase and for the groups H-DERS and L-DERS. (The standard error of the mean is in parentheses).

[2] p<0.009

Hear Rate Analysis

Results from the analysis of the mean HR values during the three different moments of the study (Baseline, Induction moment, and Regulation moment) showed a significant increase[3] of mean HR values when the frustration was induced. This may indicate that the induction of frustration was effective. A decreasing trend in the mean HR was observed after the Training Phase of ER Strategies (**Figure9**). This corresponds to the results obtained with the questionnaire, which show a decrease of the frustration level after playing respiration strategy, and attention strategy games.

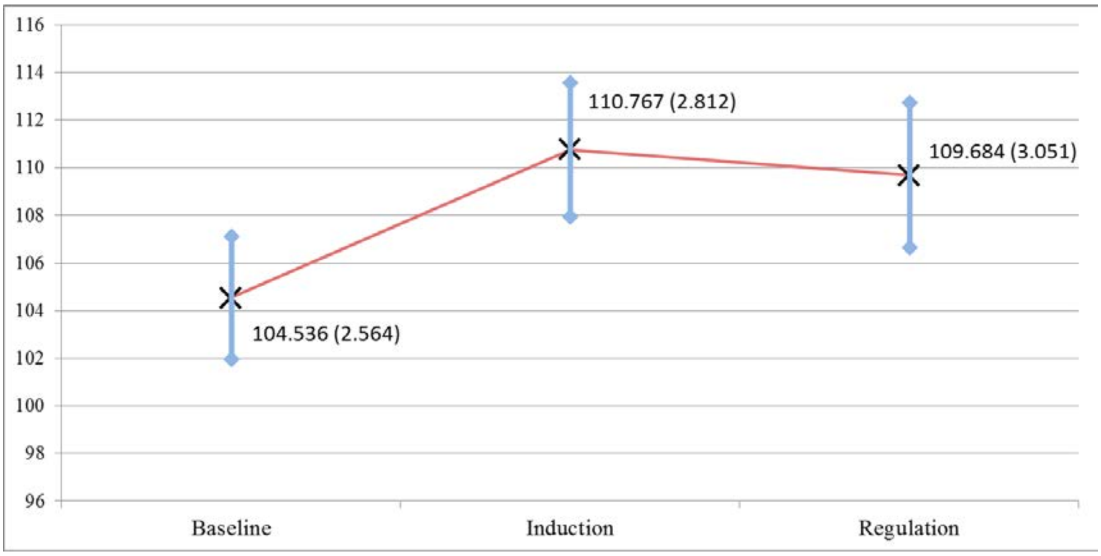

Figure 9. Mean values of mean HR of participants during the baseline, induction, and regulation phase. (The standard error of the mean is in parentheses).

Conclusion

The results obtained through questionnaires and ECG signal suggest that GT-System is effective in training and evaluation of ER strategies in the adolescent population. However, we are aware that the population used for this evaluation was a non-clinical population. Therefore, in order to confirm the efficacy of the system a future evaluation with a clinical population (i.e., with adolescents who have been diagnosed an ER disorder) is needed.

Meanwhile, we have already in process of developing a second version on GT-System with some improved features such as the use of other physiological signal, introduction

[3] $p<0.001$

of biofeedback techniques, and improvement of user-system interactivity by introducing Microsoft Kinect.

We have also planned to develop more games to train and evaluate other emotional states in adolescents, such as sadness, and happiness.

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