Virtual Reality and Serious Games for Stress Reduction with Application in Work Environments

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Abstract: This paper proposes a VR – based gamified approach aiming to reduce stress levels in work environments. This idea employs a standalone VR headset for immersion in a peaceful virtual environment, guided deep breathing exercises, sensing of heart rate and electrodermal activity for the estimation of stress, and feedback to the VR environment. For the qualitative and quantitative assessment of stress levels two sensors were used, Scosche Rhythm+ for monitoring heart rate signal (HR) and Moodmetric Ring for monitoring the EDA (electrodermal activity) signal. As a preliminary work, a series of stress-inducing batteries were created, including different stressful conditions that may resemble real life conditions (e.g., at work). Experiments with volunteers were conducted, to investigate the stress response before and during a stressful situation, as well as after VR-based relaxation. The signal fluctuation over time and the correlation between HR/EDA signals were explored towards selecting the optimal metric for the representation of the real stress level. The results of this preliminary study are relevant for the timely estimation of stress levels and the provision of a simple and useful tool for the immediate decrease of stress in various real-life environments such as work environments.

1 INTRODUCTION

The rapid evolution of VR technologies has created great expectations regarding their potential exploitation in the medical research domain or in the therapeutic procedure (Pourmand, 2017). At the same time, the development of serious games emerges as an alternative solution to classic therapeutic approaches (Lau, 2017). Serious games promise to convert parts of therapy and prevention into a pleasant procedure, enhancing patients' psychological involvement, without limiting the quality of the expected therapy results.

The exploitation of VR technology for the development and implementation of serious games or gamified approaches aiming at confronting anxiety, stress or other neuropsychological issues (Valmaggia, 2016) is widely accepted by the scientific community, since the advantages of this approach seem to have potential (Ferreira, 2002). Furthermore, the simultaneous collection of biomedical signals could indicate certain stressors, opening new approaches in stress prevention. The characterization of stress level would be based on the observation of the collected signals and the environmental conditions that stimulate stress.

The aim of this paper is to propose a serious game in VR environment for stress reduction with potential implication in work environments. Specifically, our main interest is to contribute in stress reduction in office environments, where the emergence of stress could be related with high levels of potentially stressful working conditions (i.e., job demands) and lacking resources to deal with these demands (Karasek, 1979). To do so, we test the effectiveness of an VR intervention aiming at promoting relaxation techniques to reduce stress, such as deep-breathing (McCallie, Blum, & Hood, 2006; Richardson & Rothstein, 2008).

The above issue has not been widely addressed. Thoondee and Oikonomou (Thoondee, 2017) developed a VR application for Oculus Rift that tried to address work stress by exposing workers to peaceful environments in order to facilitate their relaxation during breaktime. A similar approach (Ahmaniemi, 2017) used Gear VR headset and

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various sensors for the collection of physiological signals, such as electrocardiogram (ECG), photoplethysmogram (PPG), galvanic skin response (GSR) and blood pressure (BP), to detect and address work stress. User experience was investigated via questionnaire. Results suggested that the GSR signal better captured stress than the other collected signals. Another approach (Salkevicius, 2019) was mainly trying to trace stress levels with the collection of physiological signals during the exposure in VR environments. The collected physiological signals were blood volume pressure (BVP), galvanic skin response (GSR) and skin temperature.

Our idea is to develop an integrated system of sensors and VR serious gaming in order to immediately assess and address stress, combining ideas that have been tested in the existing literature. The main goals are presented in the following points:

1. To develop a calm, peaceful environment where visual guidance for deep breathing is offered for stress reduction. The user – system interaction is reduced to the minimum level for relaxation purposes.
2. To connect a heart rate sensor with the application for the acquisition of the signal and to add visualized feedback depending on the changes in heart rate values.
3. To simultaneously collect EDA and heart rate signal in order to assess users' stress levels and how these change during the users' interaction with the virtual environment.

2 METHODOLOGY

In this section, the chosen software development tools and sensors is be presented. Then, a brief description of the steps followed during the project's development are mentioned. Lastly, the serious game and the experiment protocols are presented.

2.1 Sensors

For the purposes of this project the following two commercial sensors were used.

2.1.1 Scosche Rhythm+

Scosche Rhythm+ is a simple BTLE sensor (Low Energy Bluetooth Device) that captures heart rate signals and can be connected to a proper device via Bluetooth in order to present, analyse and save the extracted data (https://www.scosche.com/rhythm-plus-heart-rate-monitor-armband).

This device provides an affordable and easy solution for monitoring heart rate, with acceptable accuracy in office situations (not intense exercise) as previously found (Navalta, 2020), which was suitable for the purposes of the project. Scosche Rhythm+ was also the sensor that was opted to be connected to the VR application for convenience reasons.

It must be noted that the HR signal is made available every second, which allows the depiction of HR over time and the calculation of standard deviation. However, it does not capture other heart rate variability features (Castaldo, 2019) that might be more relevant to stress level estimation.

2.1.2 Moodmetric Ring

Moodmetric Ring (https://moodmetric.com/) is a commercial sensor that uses a patented processing algorithm to analyse electrodermal activity. This analysis provides as an output an index number that indicates the user's stress levels. The extracted signal that was used in this project is not the raw signal of electrodermal activity, but the signal of the above index number. Despite of the fact that the raw data of EDA signal could be accessed, we used the Moodmetric index value signal as its use in relevant studies has been promising (Pakarinen, 2019). The stress levels are categorized as showed in figure 1.

Moodmetric Ring is a sensor that assembles various advantages, such as handiness, easiness to use and collect objective data of everyday life situations, comparability between users, robustness to motional artifacts etc.

Index value	Interpretation
0 – 20	Calm
21 – 40	Serene
41 – 60	Active
61 – 80	Worked – up
81 – 100	Running high

Figure 1: Stress levels categorization.

2.2 Development Tools

For the development of the programming part of the project and the depiction – analysis of the collected signal, a combination of four software programs were used.

Unity (https://unity.com/) was used to develop the main application of the project, the deep breathing exercise environment, linking it with the VR mask Oculus Go. Android Studio was used in order to develop the needed android library for the application – sensor connection via Bluetooth (https://developer.android.com/studio). RStudio (https://rstudio.com/), an integrated development environment for R that gives access to free and open-source libraries for data analysis and visualization, was used for the depiction of the collected physiological signals, HR and Moodmetric index value, during the experimental phase. Lastly, PsychoPy3 (https://psychopy.org/), an open-source software written in python that provides an integrated environment of tools for the development of simple applications aiming at psychological research, was used for the development of a Stroop test application (Scarpina, 2017) needed for the experimental phase of the project.

2.3 Design Methodology

The steps followed to achieve the goals of the project are summarized in the following points:

1. Selection and design of the serious game for stress reduction after reviewing the existing literature and discussion with special therapists – psychologists. Deep breathing exercise visualization in a peaceful virtual environment was selected.
2. Development of the serious game in Unity game engine for implementation on android operating system and, specifically, VR mask Oculus Go.
3. Development of an android library for the successful connection of the application and the Scosche Rhythm+ sensor via Bluetooth.
4. Integration of the Bluetooth android library in Unity as a plug – in to exploit its functionality. The data collected was displayed in the application's environment and saved after each session with the prospect to introduce environmental feedback based on the value of heart rate.
5. Planning of preliminary and final experiment protocols with the following main stages: initial relaxation, stress stimulation activities (Palanisamy, 2011), final relaxation (with and without the use of deep breathing exercise application). During the experiments the use of both sensors was deemed necessary.
6. Use of an one-item self-report, questionnaire prior and after the stress stimulation activities and after the relaxation exercise to complete the final experiment protocol and to provide the analysis with additional information.
7. Implementation of User Experience Questionnaire (UEQ, https://www.ueq-online.org/)
8. Depiction of the collected signals and statistical data extracted from the self-report questionnaires.

2.4 Game Design

The development of the serious game aims to function both as a guide for deep breathing and as a peaceful 3D environment that precipitates user's relaxation. It consists of one main scene. Before the construction of the scene, the following free asset packages were necessary:

- Fantasy Forest Environment asset package for environmental design. The scene was set in a forest virtual environment (https://assetstore.unity.com/packages/3d/environments/fantasy/fantasy-forest-environment-free-demo-35361) since empirical evidence suggests that walks and in the nature and relaxation activities facilitate recovery from job stress (de Bloom et al., 2017).
- Oculus integration asset package which provided necessary tools for the final implementation on Oculus Go.
    - Audio files as soundtracks in the application.

The main scene is presented in figure 2. The scene consists of five objects:

- Terrain: the forest environment of the scene.
- OVRCameraRig: the main camera of the scene, an extended camera object extracted from Oculus integration tools.
- Sphere: a centered sphere on main camera that simulates the rate at which the user is advised to take breaths. When the sphere's volume is augmented, its color turns white and the user is advised to inhale at the rate of its growth. While the sphere's volume is reduced, its color turns red and the user is advised to exhale at the rate of its reduction.
- A text component used to display the heart rate extracted from Scosche Rhythm+.
- An audio file for soundtrack.

Figure 2: Game's snapshot.

In figure 3 the architecture of the system is displayed. As the system's functional diagram implies, there are three main modules: the virtual forest environment where all the game objects are displayed, the sphere that undertakes the role of visual guidance for deep breathing and background functionality parts that contributes mainly in Oculus Go – Scosche Rhythm+ connection and the storage of the captured HR signal.

Two C# code files were developed to determine the behaviour of the game's objects.

- Spiral.cs: this file determines the behaviour of the sphere, thus determines the changes in sphere's volume and its colour. Furthermore, this file ensures that after two and a half minutes the application will end automatically. This duration was selected based on Allen et al. (2002) who found that employees who were trained in two-minute "mini-relaxations" experienced reductions in stress equivalent to that of employees who were taught 20-minute Abbreviated Progressive Relaxation Training (see also, Pollak Eisen et al., 2008).
- BLE.cs: this file ensures the application – sensor connection by activating the Bluetooth service via the developed android plug – in. Moreover, via this code the heart rate values are displayed on the main screen each second and are saved after the end of the application's time.

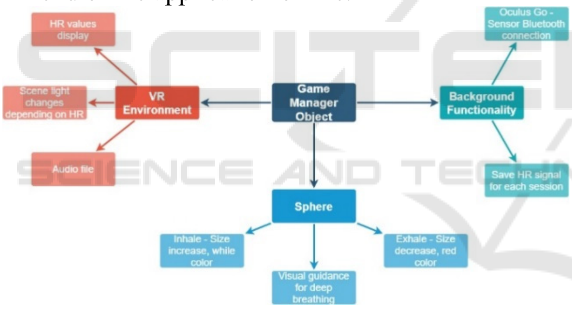

Figure 3: System's architecture.

2.5 Experiment Protocols

Two different protocols were designed for the experiments that were conducted, one preliminary and one final. Volunteers were asked to wear properly the two sensors throughout the experiments. For the stress stimulation stage three different activities were selected because they were found to stimulate stress levels and to some extend (e.g., calculations) resemble work tasks that may stimulate stress reactions. The three activities were: arithmetic calculations (finding the next element in an alphanumeric sequence, solving math puzzles, easy math tasks), a First Person Shooting Game (Xonotic, https://xonotic.org/) with rapid and intense environmental changes and the Stroop test.

2.5.1 Preliminary Experiment Protocol

Figure 4: Stages of preliminary experiment protocol.

The preliminary experiments were conducted in order to modulate a first opinion regarding the two signals and their accuracy on the indication of stress levels. As shown in the diagram of figure 4, the preliminary experiment protocol consisted of the following three stages:

1. Initial Relaxation stage (5 minutes): the volunteer was asked to relax for 5 minutes and stop all his/her activities.
2. Stress stimulation stage (10 – 15 minutes): the volunteer was asked to carry on with one of the selected activities.
3. Final Relaxation stage (5 minutes): the volunteer was asked either to relax for 5 minutes or to wear Oculus Go and use deep breathing exercise application for 2,5 minutes and then relax another 2,5 minutes.

2.5.2 Final Experiment Protocol

Figure 5: Stages of final experiment protocol.

The final experiment protocol was designed based on the results of the preliminary experiments. This protocol is an extended version of the previous one and included self-assessments of stress. Another difference between the two protocols is the extended stress stimulation stage, where a combination of the mentioned activities was implemented to better approach stressful conditions. Thus, the 6 stages of the final experiment protocol were (figure 5):

1. Initial Relaxation stage (5 minutes): volunteers was asked to relax for 5 minutes, thus, stop all their activities.
2. Questionnaire: volunteers were asked to complete a one-item self-report scale assessing stress after the initial relaxation stage.
3. Stress stimulation stage (17 minutes): volunteers were asked to carry on with three selected activities. Firstly, they had to perform arithmetic calculations (5 minutes), then to play a First Person Shooting Game (Xonotic – 10 minutes) and finally to take the Stroop test (2 minutes).
4. Questionnaire: volunteers were asked to complete the one-item self-report scale assessing stress after stage 3.
5. Final Relaxation stage (5 minutes): volunteers were asked either to relax for 5 minutes or to wear Oculus Go and use deep breathing exercise application for 2,5 minutes and then relax for another 2,5 minutes.
6. Questionnaire: volunteers were asked to complete the one-item self-report scale assessing stress after stage 5.

3 RESULTS

In this section we are going to present indicative results of preliminary and final experiments. After the presentation of the results, some of the main conclusions are going to be summarized.

3.1 Preliminary Experiment Results

The results of the preliminary experiments will be discussed in this subsection. Two students volunteered in this part of the experiments, both female and not quite familiar with VR technologies. The experiments were regarded as an easy, pleasant procedure by the volunteers. They were asked to wear both sensors during the experiments. The diagrams extracted as results are depicting heart rate signal, Moodmetric index value signal and the correlation between the two signals. The shading logic in Moodmetric index value is following the categorization presented in figure 1, with 5 zones, from green corresponding to ‘calm’ (index value 0-20), to red corresponding to ‘running high’ (index value 80-100).

The volunteers were asked to follow the protocol, although there was an extension in the recording time to get more information about the correlation of the two signals and their function as stress indicators. The results that are presented in figure 6 are extracted from the experiment that used the Stroop test as stress stimulation exercise. The test began at 17:55 and finishes 5 minutes later. These results refer to volunteer 1.

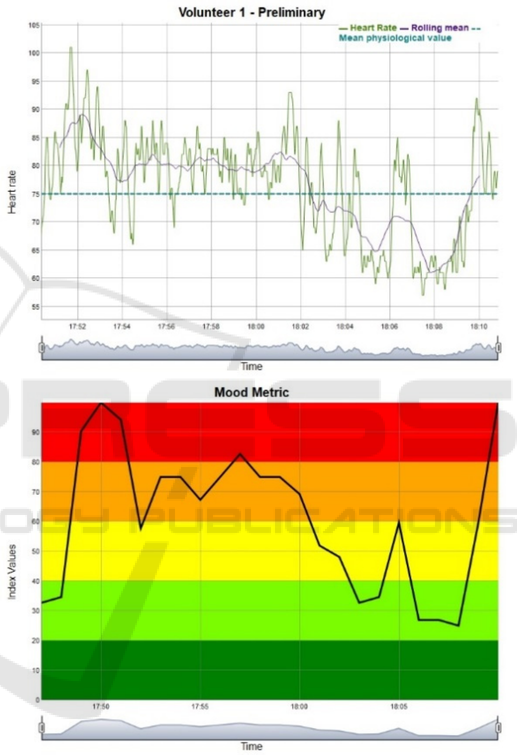

Figure 6: Preliminary experiment – Heart rate – Moodmetric index value diagrams – Stroop test.

The results do not lead to clear findings. The two signals seem to correlate with some delay, although this varied per volunteer. Even though the Moodmetric index value signal seems to more accurately depict the changes in stress levels, it is interesting that whether HR or EDA show more clear stress-related fluctuations depends also on the volunteer. The main problem that was addressed during the preliminary experiments was that none of the stress stimulation activities seemed to activate volunteers. To address this problem, this stage of the experiment was extended in the final protocol as described above.

3.2 Final Experiment Results

In this subsection, the final experiment results are discussed. Four volunteers participated in this experiment, two female (the same as in the preliminary experiment) and two male students that were familiar with VR technologies and gaming environments. As above, the results that will be presented refer to volunteer 1. In this experiment, the impact of Oculus Go application was investigated. Thus, the results will be the depiction of the two signals without/with the use of Oculus Go mask.

The results of the first volunteer present positive reaction with the use of Oculus Go application regarding its impact on stress levels (figures 7, 8). There seems to be a slight tendency of reduction during the use of the VR mask. This conclusion is based on the observation of Moodmetric index value signal, as heart rate signal on both occasions presents insignificant changes. The questionnaire results are displayed in table 1. These results support the hypothesis of the positive Oculus Go application impact on stress levels from the point of view of the volunteer.

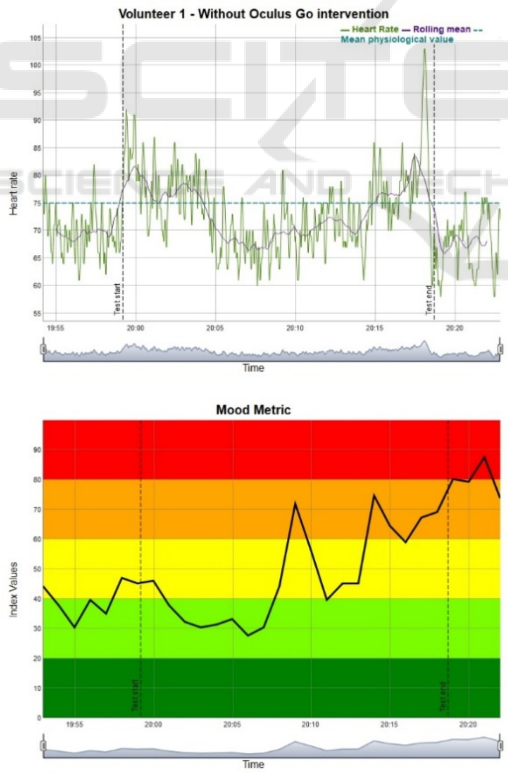

Figure 7: Final experiment – Heart rate – Moodmetric index value diagrams – without Oculus Go intervention. The two vertical lines delimit the start and the end of the stress stimulation stage respectively.

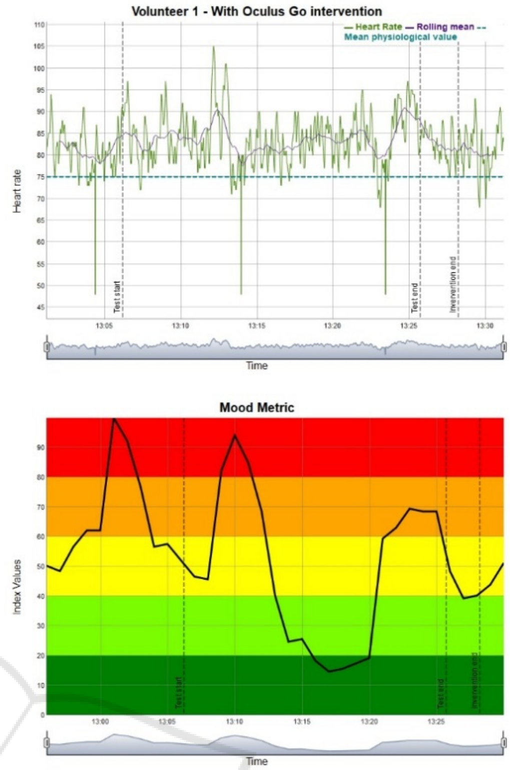

Figure 8: Final experiment – Heart rate – Moodmetric index value diagrams – with Oculus Go intervention. The three vertical lines delimit the start, the end of the stress stimulation stage and the end of Oculus Go intervention respectively.

The rest of the results are less clear. The two first volunteers (female) were not that familiar with First Person Shooting Games and this fact seemed to affect positively the capacity of the protocol’s combination of activities to stimulate stress. On the other hand, the last two volunteers (male) were more familiar reacting with this virtual environment and the stress stimulation was not that successful. Furthermore, it was again observed that whether HR or EDA show more clear stress-related fluctuations depends on the volunteer. The HR standard deviation signal presented better correlation with Moodmetric index value signal, suggesting that it could work as a better stress indicator than HR. The Moodmetric index value signal fluctuations continued to present a clearer picture of stress levels, while the changes of HR over time were insignificant in most occasions. Finally, all volunteers stated in the questionnaire that the use of the mask and deep breathing application actually relieved them of stress, despite the fact that this was not depicted on the collected signals on all occasions. The use of Oculus Go application was translated into slightly faster tendencies to recover from the previously increased stress levels. Thus, there was indeed a better match of the Oculus Go with the self-reports.

Having regarded as a more accurate stress indicator the Moodmetric index value signal, most of the results showed that the use of mask relieves slightly from stress. Nevertheless, the stress stimulation stage of the protocol has to be reconsidered in order to come to more concrete conclusions.

Table 1: Questionnaire results with and without Oculus Go intervention. The letter V stands for volunteer. Questionnaire scale: 1 – 5 (No stress – Extreme stress).

Volunteers	Question 1	Question 2	Question 3
V1 without	2	3	3
V1 with	3	3	2
V2 without	2	2	2
V2 with	2	3	2
V3 without	3	2	3
V3 with	2	2	1
V4 without	2	3	2
V4 with	3	3	2

3.3 User Experience Questionnaire (UEQ)

The User Experience Questionnaire was implemented to collect opinions for the developed Oculus Go application. Ten volunteers accepted to test the application. The age of participants ranges from 23 to 59. Most of the answers were encouraging. The technology of Oculus Go mask certainly played decisive role in this direction, as most of the volunteers were not familiar with VR mask technology.

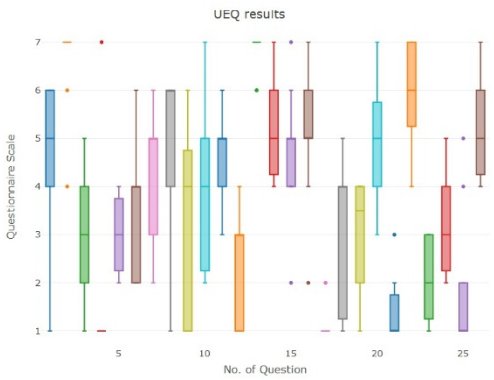

Figure 9: User experience questionnaire – boxplot of answers per question.

The results of the UEQ are presented in figure 9. Most of the lower and higher mean scores interrelate with positive comments about the system pointing out mainly its attractiveness, with one exception that refers to the system's predictability. The mean score does not contain necessarily enough information. The recitation of the UEQ is necessary. These results suggest that the application is intuitive, user – friendly, easy to learn and to use and quite clear regarding its purposes. The VR environment is regarded as satisfactory, pleasant or even attractive.

4 DISCUSSION

The purpose of this paper was to present the development of a VR application for the reduction of stress levels. To this end, two experiment protocols were designed and conducted, and indicative results were presented. Although the number of volunteers that participated in the experiments does not allow safe conclusions, the results indicate the potential of the project, but also the need for new experiment protocols, more elaborate signal processing and enhancements on VR environment.

Limitations of this attempt are the small number of volunteers who participated in the experiments and the need to enrich and standardize the stress stimulation stage in experiment protocols to better simulate working environment conditions and responses by different stress-related categories of people.

Future work has to invest in the direction of the VR system enhancement and its harmonic cooperation with commercial sensors. Access to instantaneous heart rate and HRV features would better enable the quantification of stress levels. Overall, it is necessary to detect the right stress indicators in order to design a more robust system with the capacity to accurately address the problem of work stress. One of the possible future expansion of this work could be the design of a suite of VR serious games for the treatment of chronic stress or anxiety disorders.

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