Effects of Immersive Virtual Reality on the Heart Rate of Athlete's Warm-Up

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Abstract. An adequate warm-up prior to intensive exercise can bring benefits to athletes, these requirements may vary depending on the physical activity and the training needs. The immersive virtual reality could have benefits in the warm-up and it can be determined by physiological data of the athlete. This work presents a mobile virtual reality application to stimulate the warm-up of an athlete using a standard treadmill, where the developed application is composed of a pleasant and stimulating environment. A Smartphone and the Gear VR are used as an HMD device, and wireless headphones are placed in the users, in addition, the heart rate of the athletes is monitored using a Polar H7 sensor. Experimental results are obtained in athletes with similar characteristics and conditions, identified a direct relation of the virtual environment with the pulsations per minute (ppm), denoting pulsations greater than usual in case of the stimulating environment and lower pulsations for the pleasant environment. Finally, a usability test is performed that shows the level of sociability of the system.

Keywords: Virtual reality · Immersion · Heart rate · Warm-up · Usability

1 Introduction

Immersive virtual reality offers the possibility of comparing the human response in activities and processes within virtual environments with respect to situations presented in the real world, in order to analyze the perception, preference, and behavior of the user. The concurrent areas in the use of this technology are medicine, psychotherapy, and education, advantageously these immersion systems are available to almost all researchers [1]. In medicine, the user can improve the learning processes of the human anatomy, reviewing the internal composition of human parts, including complex

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elements of the brain [2]. It is also possible to study decision-making processes by applying subjective and objective evaluation techniques [3]. On the other hand, virtual neurological rehabilitation allows the patient to improve their cognitive functions even when the lesion is in the subacute period [4] and in motor rehabilitation when the patient has lost mobility, the positive effects of these applications have been demonstrated using different methods [5]. In addition, virtual reality has allowed diagnosing physical and psychological states; studies determine the consumption of methamphetamines through social virtual environments and analyzing neurophysiological signals [6]; stress levels are qualified by the variability of the heart rate in situations of tension within immersive virtual environments [7]. The development of these applications requires a correct insertion of the immersion components, as well as an adequate coherence to the responses of the virtual environment, studies show that discomfort occurs in the user due to lack of coordination [8].

To determine the benefits and usability of a virtual reality system, it is necessary to rely on surveys and physiological data that validate this information. Current technology has facilitated acquiring sensory information from the user, reducing the size of the sensors, new communication devices, and connectivity, allowing the use of multiple contact devices which are widely used in medicine [9]. The data commonly recorded are heart rate, systolic blood pressure, diastolic blood pressure, electroencephalography, core temperature, eye movement, and so forth. [10], These data allow to measure states of relaxation and stress, especially in situations of great pain and discomfort [11]. Several proposals manage to quantify the concentration of the user through real-time information and some works manage to design telemetric monitoring systems for patients [12, 13].

Sport is a human activity with a high degree of influence on the quality of life, for this reason there are multiple virtual reality games to encourage exercise and study the user's physical responses, thus, Exergame includes the virtual tracking of the body movements of the user, combining physical activity and visual feedback, achieving favorable responses according to studies [14]. Soccer experts have evaluated first-person immersive virtual training systems [15], recommending its use. To study the daily exercise or any sport activity, several data of the user-application system are required, from knowing the movements made in real time to measuring the physiological conditions affected [16], where it had seen that the more immersive the application of virtual reality, the greater stimuli are generated in the human body and reactions similar to those produced by real exercises are achieved [17]. An element of incidence are the landscapes which appear in the virtual environment, because physical activities are usually carried out in confined places, virtual training allows to improve the comfort of the user and highlight the benefits of exercising in spaces of reality virtual [18]. The intensity of exercise in active virtual reality games has been studied by oxygen consumption and heart rate, obtaining important data to determine the metabolic rate of the activity and making decisions by specialists according to the requirements [19]. Finally, the users of a football training software with immersive virtual reality presented performance improvements of up to 30% in 3 days of evaluation [20].

This work performs the analysis of warm-up on a treadmill using visual stimulation using immersive virtual environments. The purpose is to stimulate the walk by presenting landscapes and measuring the heart rate in each case, the application is developed using the Gear VR and the raw data is acquired using the Polar H7 sensor. The document has been organized in the following manner*: (ii) formulation of the problem*, the problem to be solved is analyzed and a proposed structure is presented; *(iii) Proposed system*, the components of the system are detailed; *(iv) Virtual environment development*, the implementation of virtual environments is described; *(v) Results*, the results obtained through experimentation and applying a usability test are presented; *(vi) Conclusions*, the final proposals are presented.

2 Formulation of the Problem

In physical training, the first step recommended before running exercises is warm-up, where the purpose is to prepare the muscular system for more violent or forceful movements. Technically, most athletes do not have control of the level of warm-up required for their training and the components of gyms and sports areas do not motivate the proper development of this stage of training. In professional sports, a careless warm-up can cause serious injuries and affect the health of the athlete. On the other hand, an inadequate warm-up could generate discomfort in the later phase, affecting performance. For these cases, improving the environment surrounding of the athlete could generate changes in their performance, and it is possible to influence him/her. The level of involvement of the immersive virtual reality in the warm-up phase of an athlete depends on the recreated virtual components and the devices used, this influence could be positive or negative in the user, so it is important to design properly the virtual environments to be used.

The effect produced by the virtual environment in an athlete while performing physical warm-up on a treadmill can be analyzed through a survey or using physiological data. This information can be used by specialists who make the decisions that best suit the athlete. In this context, it is proposed to develop a virtual reality application to stimulate warm-up using a treadmill while acquiring heart rate data in the user, as shown in Fig. 1. The HMD device works by means of a smartphone, using additionally a waterproof belt type sensor called Polar H7.

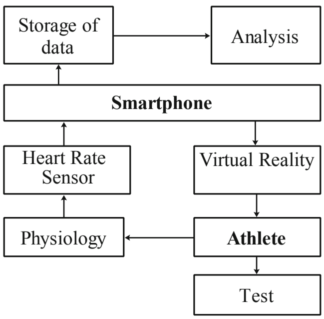

Fig. 1. Proposed structure

The implementation of virtual environments aims to stimulate the athlete through a landscape of relaxation and excitement, influencing the heart rate and motivating the mood of the user. The application can be used on a treadmill or controlled trips in fully structured areas. Finally, the information collected is compared to normal warm-up to determine the variations.

3 Proposed System

The structure of the proposed system is split into three groups: the game objects inserted in Unity, the control scripts for the virtual elements, and the external input and output devices. Figure 1 shows the structure of the system, where each component is presented (Fig. 2).

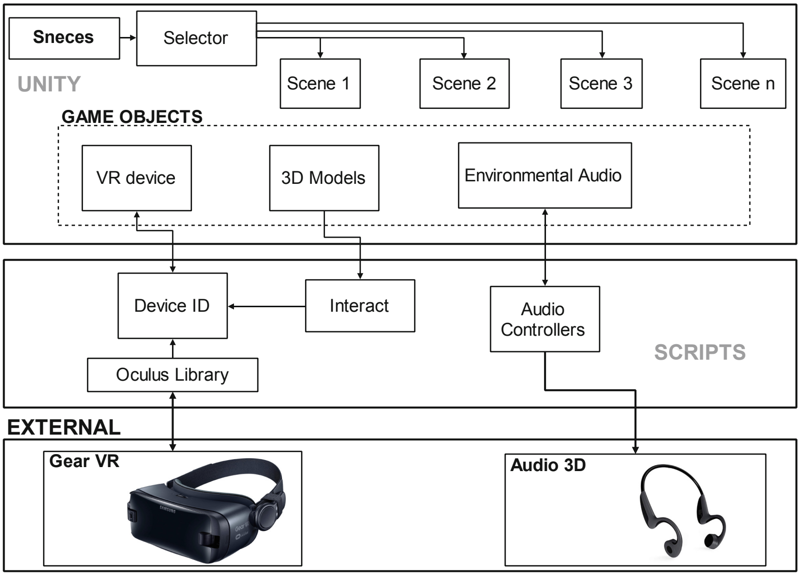

Fig. 2. System components

In Unity there are the scenes of the virtual reality environment, depending on whether it is necessary to stimulate the state of relaxation or excitement. In this stage, the 3D models which make up the landscape observed by the athlete are inserted, the scenes are independent and have their respective models; likewise, the virtual reality device is defined by a game object which allows its operation, and finally, there are game objects linked to spatial audio sources.

On the other hand, scripts allows communication between Unity scenes and external devices (HMD and headphones); they coordinate the functions of the game objects and the actions of the game; and the oculus libraries manage the Gear VR recourses. The input devices are the internal sensors of the Smartphone and the output devices are the mobile virtual reality glasses and the wireless headphones.

For the acquisition of heart rate data, an additional mobile application which receives the sensor information is used. The device used is the polar H7, this sensor is characterized by its robustness and resistance to conditions of almost any sports activity, including swimming. Figure 3 illustrates the heart rate sensor used.

Fig. 3. Heart rate sensor

4 Virtual Environment Development

Two types of environments are developed to implement the application and the functions of the virtual elements. The scene of relaxation consists of sunny days and dense vegetation, and the stimulating environment with dark scenes.

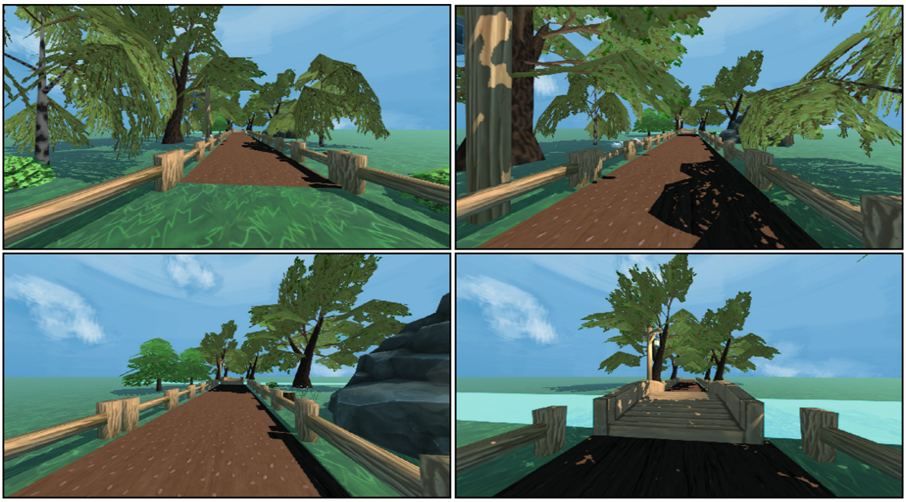

Fig. 4. Scene of Relaxation

Figure 4 shows the images of the relaxation place, a trail-like environment for the athlete's walk surrounded by relaxing attractions. The components have been entered using prefabs from multiple assets and have been placed in the scene by position parameters and rotation parameters of the scene inspector.

Figure 5 shows the images of the stimulating environment, an abandoned place which is in flames. The components have been entered in a similar way to the relaxation area and fire effects have been inserted using the Unity particle system.

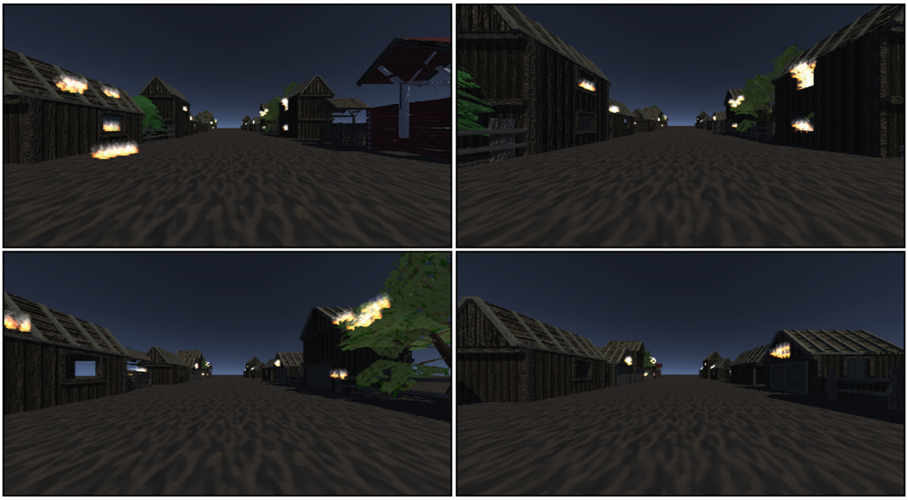

Fig. 5. Excitement environment

Regarding the movement of the user, a control script is created which allows the movement of the virtual camera in the walking area, and through *player.transform.-position*, the displacement has been designed in a cyclical manner, that is, when the player reaches the end of the route, he/she is located again at the beginning.

5 Results

Next, the results obtained using immersive virtual reality in the physical warm-up phase of athletes using a treadmill are presented. The results are evaluated using the data acquired by the Polar H7 sensor and applying a usability test of the application. Given the random and constant movement due the sport activities, for the visual output is used a Galaxy S8+ Smartphone with Gear VR, while for the output are used the Z8 wireless headphones. Figure 6 shows an experienced user the virtual reality system.

The experiments are carried out in 4 athletes who regularly attend the gymnasium of the Universidad Tecnológica Indoamérica, all male between 22 and 24 years old. The tests are performed on a standard treadmill at a constant speed of 2.5 km/h and with a duration of 10 min. In the first test, the users perform the exercise without the

Fig. 6. Athlete testing the system

Gear VR, and their cardiac responses are monitored, obtaining the data of Fig. 7, where it is observed that the athletes reach maximum peaks of 143 ppm in this period, maintaining a range of pulsations between 128 and 143 ppm in the stationary stage.

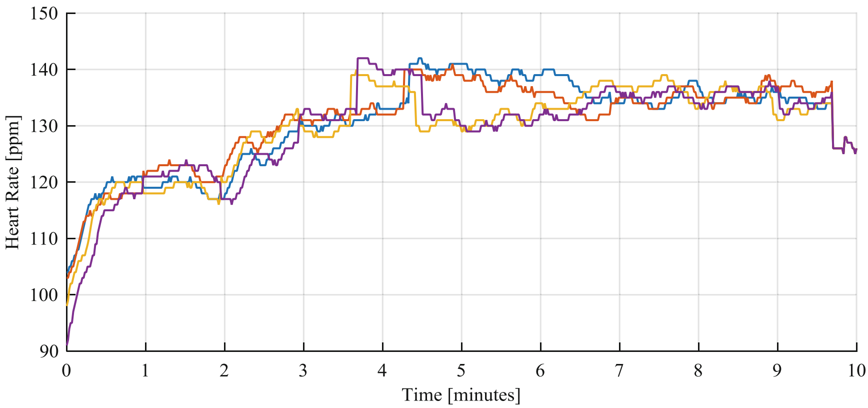

Fig. 7. Heart rate without virtual environment

Evaluating the scenes of relaxation, the individuals generated the cardiac pulses of Fig. 8, observing a maximum heart rate of 136 ppm, and maintained a range of pulsations between 122 and 136 ppm in the stationary phase, which indicates a reduction of heart rate respect to normal exercise conditions, due to the effect of relaxing place on the walk.

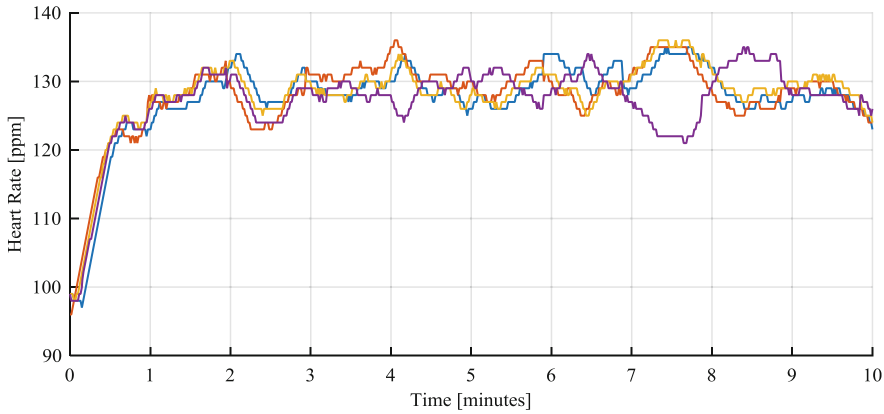

Fig. 8. Heart rate with virtual scenes of relaxation

From the experiment with the stimulating virtual environment, the heart rate signals of Fig. 9 were obtained, showing a maximum heart rate of 154 ppm, and a range of heart beats between 131 and 154 ppm in a permanent period, which indicates an increase in average heart rate with respect to normal walking conditions.

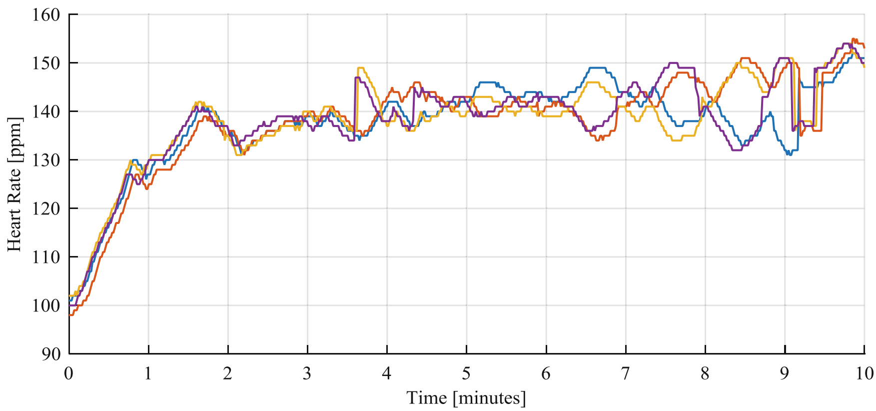

Fig. 9. Heart rate with virtual excitement environment

Figure 10 shows a comparison of the previous experiments, observing a greater heart rate in the case of experiencing a virtual environment of excitement, and lower pulsations when individuals visualize the virtual environment of relaxing. Demonstrating a clear influence of the immersive virtual reality in the physical warm-up with the conditions exposed in this work.

To evaluate the usability of this application, a SUS test is applied, widely used in mobile applications, for which the procedures detailed in [21] are used. Table 1 shows the results of the test applied in the 4 test subjects, obtaining a total of 27.25 and

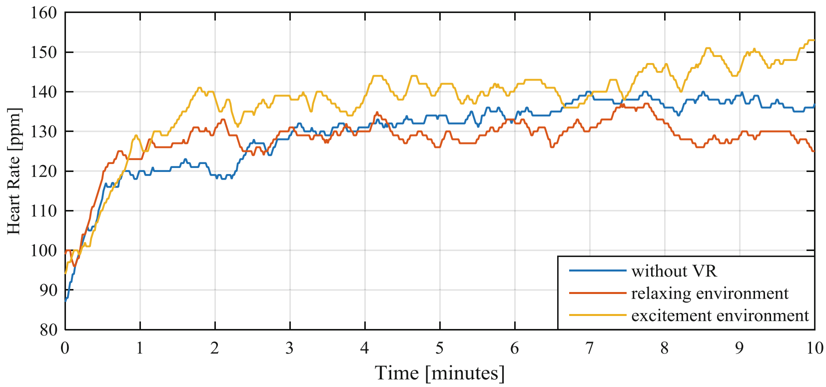

Fig. 10. Comparison of heart rate responses

Table 1. Test SUS results

Question	Score 1	Score 2	Score 3	Score 4	Mean	Operation
I think I would like to use this system frequently	2	3	2	2	2.25	1.25
I find this system unnecessarily complex	**1**	**1**	**2**	**1**	**1.25**	**3.75**
I think the system is easy to use	4	4	4	4	4	3
I think you would need technical support to make use of the system	**1**	**2**	**2**	**3**	**2**	**3**
I find the various functions of the system quite well integrated	3	4	2	3	3	2
I have found too much inconsistency in this system	**2**	**1**	**1**	**2**	**1.5**	**3.5**
I think most people would learn to make use of the system quickly	4	3	4	4	3.75	2.75
I found the system quite uncomfortable to use	**2**	**2**	**2**	**1**	**1.75**	**3.25**
I have felt very safe using the system	2	2	2	1	1.75	0.75
I would need to learn a lot of things before I can manage the system	**1**	**1**	**1**	**1**	**1**	**4**
Total						27.25

multiplying by the factor 2.5, a final assessment of 68.125 is obtained, which can be considered as in the acceptance limit, indicating that improvements are required for the recurrent use of the system. The test shows resistance to the use of the application on a frequent basis by users, they also consider that virtual reality functionalities have not been well integrated, and they do not feel safe using the system.

6 Conclusions

The work presents the influence of an immersive virtual reality application in the physical warm-up phase of an athlete using a standard treadmill. For this purpose, a virtual environment of relaxation and another virtual scenario of excitement are implemented, the Gear VR is used to perform the experimental tests and the heart rate is monitored by a specialized sensor. The virtual environments are developed using the basic characteristics of Unity, considering that the user experiment in first person, where wireless sports headphones are used to increase the level of immersion.

The results obtained show notable differences in the heart rate of the athletes, starting from the analysis under normal training conditions which allow to compare the effects of the system on the user. The virtual environment of relaxation maintains a heart rate lower than the normal and the exciting virtual environment produces a higher heart rate, conditions which can be used by a specialist to obtain the desired effects in the subsequent intensive training. In addition, the usability of the applications is evaluated, demonstrating that some shortcomings in the system can be improved, mainly related to comfort and user satisfaction.

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