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Original Article

Application of Virtual Reality in the Treatment of Claustrophobia in Adolescents

Orlando Iparraguirre-Villanueva[1], Carlos Perez-Benito[2], Diego Torres-Murga[3], Andrés Epifanía-Huerta[4]

[1,2,3]*Faculty of Engineering and Architecture, Autonomous University of Peru, Lima, Peru.*
[4]*Faculty of Engineering, Technological University of Peru, Chimbote, Peru.*

[1]*Corresponding Author: oiparraguirre@ieee.org*

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Abstract - *Claustrophobia is an anxiety disorder that requires the priority of the medical profession. The causes of claustrophobia are not fully understood, but it is believed that there may be a genetic factor. People suffering from this disorder may experience physical and emotional symptoms such as sweating, dizziness, panic, and shortness of breath when in enclosed spaces. The aim of this work is to develop a Virtual Reality (VR) application for the treatment of claustrophobia. The Extreme Programming Methodology (XP) and the Unity graphics engine were used to develop the application. To validate the experiment, we worked with a sample of 50 students with an average age of 15 years. The findings showed that the VR application did not significantly increase the Beats Per Minute (BPM) of the participants, who all registered between 60 and 100 BPM. However, it did manage to increase the feeling of realism when wearing the VR goggles. In conclusion, the application of VR as a tool to treat claustrophobia allowed the recreation of realistic claustrophobic scenarios in which participants were tested to assess their behavior and cardiac BPM.*

Keywords - *Virtual reality, Claustrophobia, Disorder, Anxiety disorders.*

1. Introduction

Claustrophobia is a disorder also known as an anxiety disorder and is classified as a situational phobia [1]. Statistically, phobia is the most common anxiety disorder, affecting approximately 15% of women and 7-8% of men [2]. Surprisingly, only half of those affected seek treatment [3]. Claustrophobia is characterized as a fear of enclosed spaces and physically restrictive situations [4], causing two types of fears, fear of suffocation and fear of constraint [5]. The fear response can also be triggered by perceptual stimuli [6], which can stem from situations such as getting stuck in narrow spaces, going through tunnels, trains, and planes, driving in traffic, or getting stuck in an elevator. Claustrophobia can be generated, especially during childhood and adolescence, in an irrational way. It causes accelerated heart rate, sweating, high blood pressure, dizziness, fainting, chills, shivering, choking sensation, etc. In general, there are several methods to treat this type of anxiety disorder, such as psychological therapy and antipsychotic drugs [7]. However, the most effective is exposure therapy, in which the person is exponentially exposed to their anxiety situations to understand their irrational fear.

Unfortunately, this process is often costly. On the other hand, new technologies such as VR help us simulate claustrophobic environments to explore their feasibility in therapeutic applications. VR is a set of techniques and systems used to produce a 3D virtual world, which stimulates the user's perception, including the 5 senses. It has 3 main elements: three-dimensional presence, autonomy, and real-time interaction [8]. VR has had a significant advance in different fields, mainly in medicine, which allows the treatment of many psychological disorders through simulations. This generates a pleasant user experience in an immersive environment digitally [9]. VR-based therapies create a controlled environment to help users experience and overcome their fears without being exposed to dangerous situations in the real world. This gives a significant advantage to mental disorders treatment. With claustrophobia and VR, greater control, flexibility, and customization of the virtual environment is possible [10].

Considering that VR is a great technology for creating virtual environments in an effective, exponential, and cheap way [11], it could be very useful when performing exposure therapies to deal with claustrophobia since it is of vital importance to improve the quality of life of people who suffer from it [12]. In this way, it opens a lot of possibilities to explore places that they do not dare to know and experiences to live for fear of suffering from an anxiety disorder. Anxiety disorders have a great impact worldwide. For example, the countries with the highest percentage of anxiety disorders in

2019 are: Portugal with 8%, Brazil with 7.4%, Iran with 7.3%, France with 6.3%, the United States with 5.7%, Spain with 4.9% and Austria with 6%, New Zealand with 7.3%, among others [13], as shown in fig. 1.

Therefore, the goal of this project is to create a VR application to treat claustrophobia in a controlled environment. In this article, we will start by reviewing related work in Section 2. Then, we will explain and develop our methodology in Section 3. In Section 4, we will discuss the results obtained. Finally, in Section 5, we will present our conclusions.

2. Related work

Nowadays, many people suffer from claustrophobia without knowing there are many methods to treat it. It is necessary to promote and analyze the treatment of claustrophobia to effectively avoid anxiety attacks and the discomfort it causes. VR research papers were reviewed for this purpose. For example, in the paper [14], the aim of this study was to help psychologists and psychiatrists assess and manage various levels of fear in patients. The study examined the flooding and gradual exposure methods for treating fear and phobias. At the same time, it was thought to recreate various scenarios for existing phobias. Different results were obtained depending on the phobia treated. For the most part, various symptoms were generated thanks to VR.

In conclusion, the authors comment that auditory and visual illusions are paramount to recreating immersive experiences. This is so that the user believes what he sees and hears. Similarly, the article [15] investigated VR as a screening device for phobia disorders. Simulated phobia onset scenarios were developed in a virtual environment that attempted to put the person against the manifestations of the phobia. One metric used in this research was BPM. As a result, it was possible to generate signs of phobias in people suffering from this disorder.

In the paper [16], the authors examined the acceptability of In Vivo Exposure therapy (IVE) and Virtual Reality Exposure (VRE). They worked with 186 participants who were offered the option to try IVE and VRE. VRE had an acceptance rate of 58%, and IVE had only 35%. In conclusion, VRE is considered more acceptable than IVE, indicating that working with VRE would treat more phobic individuals. In the paper [17], the authors examined the effects of Virtual Reality (VR) and Augmented Reality (AR) on anxiety in 34 participants.

They measured heart rate (BPM) during the process and analyzed anxiety symptoms after each trial. As a result, they concluded that VR and AR generated discomfort and a significant increase in BPM. However, there was no significant difference between them. In conclusion, RV and RA induced obvious anxiety, which was reflected physically. In this study [18], researchers delved into the potential of VR to provide patients with safe and controlled environments that could trigger claustrophobia. They created several VR environments, such as an elevator, a tunnel, and a small, enclosed room.

The results revealed that exposure to these virtual environments significantly reduced anxiety and claustrophobia. In conclusion, VR can create safe and controlled environments for patients, so it can decrease claustrophobia. To conclude, the article [19] examined the efficacy of ERV therapy for claustrophobia from clinicians' point of view. Seven professional clinicians evaluated eight VRE sessions, scoring each review. As a result, six of the seven physicians endorsed VRE. The evaluators indicated that the elevator simulator has considerable potential for use in exposure therapy.

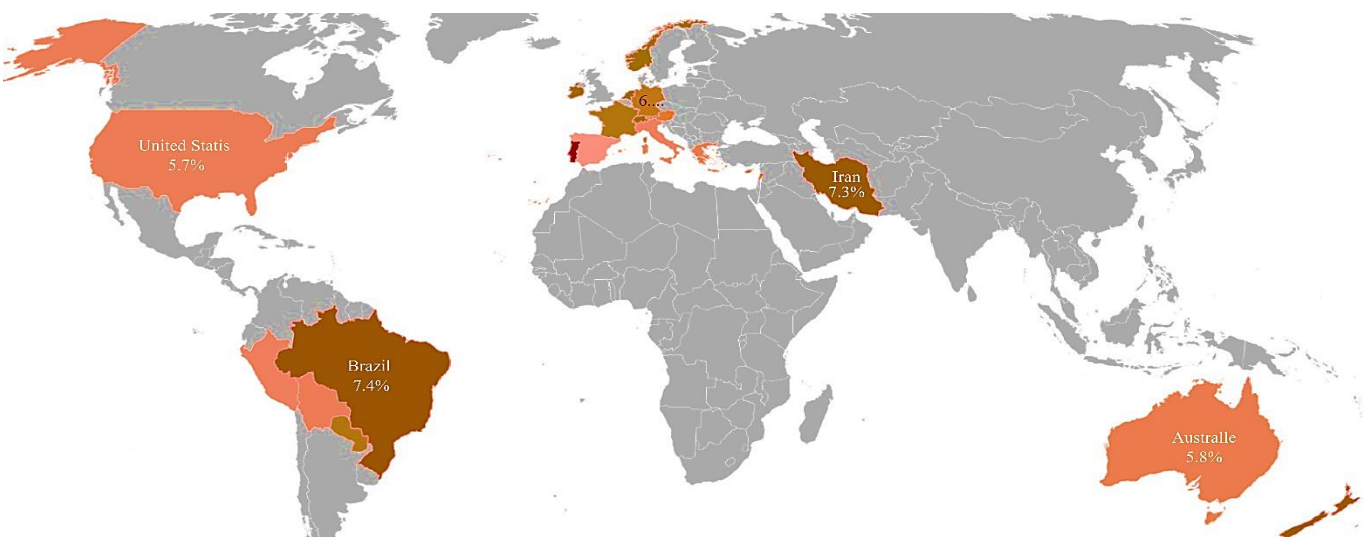

Fig. 1 Estimated percentage of people with anxiety disorders, diagnosed or undiagnosed, based on representative surveys, in 2019

3. Materials and Methods

This section presents the main theories underpinning this work. A case study is also developed. In this work, the XP development methodology is used to manage the project. This methodology provides good communication in pair work within the team [20]. They are used in small and medium-sized developments, where requirements tend to vary and change constantly. In addition, it contains a series of recommendations and rules divided into the areas of software management, coding, design, and testing.

3.1. VR Development Architecture

This work uses a methodology that follows the game development life cycle. This methodology is used to create digital games from the initial conception of the idea to its completion and launch. It is composed of the following phases: (1) Planning, (2) Design, (3) Coding, and (4) Testing. Next, we will proceed with the development of the case study, as can be seen in Fig. 2.

Fig. 2 VR development model

3.2. Case Development

3.2.1. Planning – Pre-Production

Nowadays, there are numerous applications and tools for developing 3D and 2D scenarios. A scenario creation engine is a software development application that provides basic components for creating environments on multiple platforms. It also provides tools for animation, physics, audio systems, and scripting, among others [21]. In this project, we use Unity3D as the engine to create the 3D virtual reality scenario, taking advantage of the tools it offers. For the game programming, lift movements, sound reproduction, character, and camera configurations, we used Microsoft Visual Studio with the C# programming language, as Unity works with this language [22].

Hardware Tools

As the main development tool, a desktop computer is used that meets the necessary components for the creation of scenarios, animations, interaction with objects, and movements in the scenario and of the player. For this purpose, a computer with the requirements specified in Table 1 is required. For this type of task, the Oculus Quest2, a VR tool that allows the implementation of the software developed in Unity, is used. The Oculus Quest2 has the components shown in Table 2 [23].

Appraisal

At this stage, the user stories were evaluated to determine the order of delivery of each story. This is demonstrated in table 3.

Iteration Plan

At this stage, the order of the user stories to be worked on is determined according to the importance of the project development. Table 4 shows the final order.

Table 1. Computer components

Item	Description
Processor	Ryzen 7 5700X
Ram	16GB 3200
Storage	M.2 mp600 pro xt gen 4
Video card	RTX 2060 NVIDIA
Operating System	Windows 10 PRO

Table 2. Oculus quest2 components

Item	Description
Processor	Snapdragon XR2
Storage	64/256 GB
Refresh rate	90Hz/72 Hz
Resolution	1,920 x 1,832 per lens
Operating System	Android

Table 3. Valuation and estimation

User History	Business priority	Development risk	Estimated points
Access to the application	9	9	9
Viewing the scenario	9	8	7
Movement on the stage	6	6	6
Animation display	7	6	7
Interacting with targets	4	4	4

Table 4. Iteration plan

Iterations	User History
1st iteration	H1 Access to the application
	H2 Scenario display
2nd iteration	H3 Animation display
	H4 Movement on the stage
	H5 Interaction with objects

3.2.2. Design – Game Design

To begin with the first iteration, we analyzed the various scenarios that could trigger a claustrophobic reaction. It was decided to focus on elevator failure, as this is the most likely scenario to occur. After the analysis, the scenario was designed, consisting mainly of two floors and an elevator, as shown in Fig. 3. The person will be able to interact with these elements, being placed in a situation of normal elevator use and simulating elevator failure.

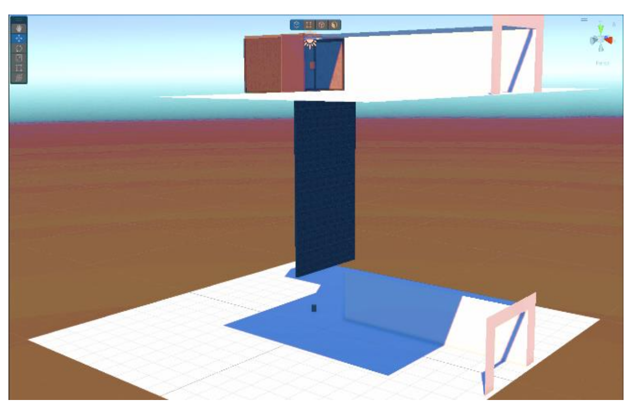

Fig. 3 Screenshots of the elevator scenario creation in the unity3D engine

Fig. 4 Screenshots of the elevator interior in the unity graphics engine

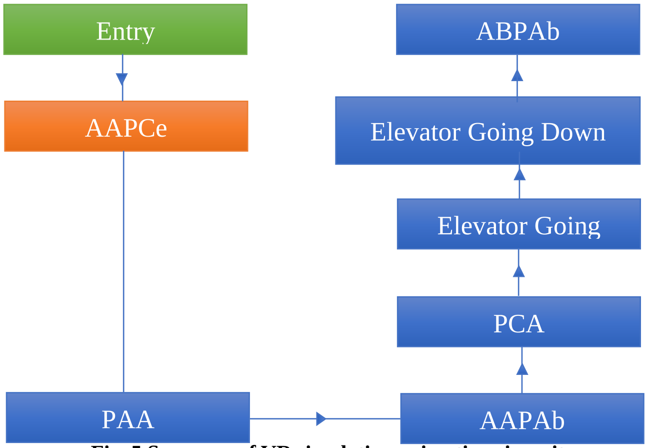

Fig. 5 Sequence of VR simulation animations in unity

Continuing with the design, the interior of the elevator is modeled. The elevator features a complete car with a pushbutton panel and central light. In addition, as shown in Fig. 4, the elevator will have doors with animations, as well as animation of the descent and failure of the elevator.

Unity works through the sequence of object states and conditionals for an object to pass from one state to another. Therefore, the sequence of animations is shown in Fig. 5 to show the states of the objects with which the system works and how it functions.

Coding

In the third stage, we perform the coding, which will allow us to operate the system and link it with the animations and objects generated within the scenario. We will also add camera movement and user movement functions in the application. In this way, the freedom of movement that VR provides will be realized. This will give the feeling of a realistic environment without limiting physical movements.

Testing

Finally, after performing the necessary tests to verify the correct functioning of the VR application, we import the final version of the application in APK format to install it definitively in the VR viewers and start testing the participants. In Fig. 6, you can see the Oculus Quest2 in the final tests.

Participants

The participants exposed to VR treatment for the treatment of claustrophobia were 10 5th-year high school students of the Marianist institution, with an average age of 15 years. Of these, 12 were male and 8 were female.

4. Results and Discussion

This section shows the findings after applying the RV to a sample of 50 students. To this end, instruments were initially developed for the two indicators for information collection, and to validate them, Cronbach's Alpha coefficient method was used. This resulted in an index of 0.816, which determines that the instruments have a high degree of reliability. The data were then tabulated. Descriptive statistics were applied to the dependent variable, which is broken down into the dimensions: symptoms, realism, and heart rate. For the KPIs, the following indicators were analyzed: symptoms presented, feelings of realism and BPM. Three indicators were used: KPI-1, KPI-2 and KPI-3. To collect the data, an instrument was used for both the pre-test and post-test, supported by SPSS and Minitab statistical programs. This method was applied to each of the indicators. The results obtained from the 50 students of the "Marianistas" school are summarized in Table 5. Table 5 shows the mean symptom level of the students during the KPI-1 pre-and post-test. The scale conforms to a symptom rating test (SRT) where 1 is "Never", 2 is "Hardly ever", 3 is "Sometimes", 4 is "Usually", and finally 5 is "Always" in relation to the user's symptoms [24].

The vast majority falls between 2 and 3, meaning that they "Almost never" or "Sometimes" have felt symptoms of claustrophobia, and two users claim to have never felt symptoms. Similarly, KPI-2 for both pre-and post-tests, shown in Table 5, is the means of the level of perceived realism per student. Students' sense of realism is measured by a scale where 1 has "None", 2 has "Little", 3 has "Moderate", 4 has "Quite a lot", and 5 has "A lot" [25]. The vast majority fall between 1 and 2, meaning that "Nil" or "Little" have experienced realistic virtual reality experiences.

Fig. 6 Image testing of the application

Table 5. Summary of the results of the three indicators

	KPI-1		KPI-2		KPI-3	
	Symptoms (%)		RV sensations (%)		BPM	
#	Pre	Post	Pre	Post	Pre	Post
1	2.6	1.2	2	4.4	90	90
2	1	1	1.8	2.6	77	78
3	2.4	1.8	1.6	3	92	93
4	1.6	1.4	3	4	91	93
5	2.8	1.4	3	4	100	102
6	2	2.4	1.6	3.4	87	91
7	2	2.2	1	3.2	91	91
8	1	1	1.2	3.2	89	89
9	2	3.4	1	3.8	91	95
10	2.2	2.4	1	4.4	90	93
…	…	…	…	…	…	…
50	2.7	1.8	1.4	2	92	90

Table 6. Summary of normality test for indicators

Indicators	KPIs	Statistician	GL	P
User symptoms	Pre-KPI-1	0.921	50	0.10
	Post-KPI-1	0.904	50	0.10
Users' feelings	Pre-KPI-2	0.862	50	0.10
	Post-KPI-2	0.922	50	0.10
BPM	Pre-KPI-3	0.839	50	0.01
	Post-KPI-3	0.871	50	0.01

Table 7. Statistical tests to contrast the hypothesis

Indicators	KPIs	Distri-bution	Distribution Result	Statistical Test
User symptoms	Pre-KPI-1	Normal	Parametric	T-Student
	Post-KPI-1	Normal	Parametric	T-Student
Users' feelings	Pre-KPI-2	Normal	Parametric	T-Student
	Post-KPI-2	Normal	Parametric	T-Student
BPM	Pre-KPI-3	Not Normal	Parametric	T-Student
	Post-KPI-3	Not Normal	Parametric	T-Student

Table 8. Statistical tests to test the hypothesis

Indicators	Pre	Post
KPI-1: User Symptoms	1.96	1.82
KPI-2: Users' feelings	1.6	3.46
KPI-3: BPM	90.80	91.50

In this process, the significance level of 95% was also used, which implies a margin of error of 0.5%. Since the sample has less than 50 elements, it was decided to use the Ryan-Joiner statistical test (like Shapiro-Wilk) to evaluate the normality of the data [26]. This test determines whether the data follow a normal distribution or not. According to the normality tests performed and analyzed previously, it was compiled and organized as a summary in Table 6.

Once all the types of data distributions have been obtained, we proceed to verify the statistical T students test for each one of them to contrast the hypothesis of this work. Table 7 shows the type of statistical test to be used according to the distribution obtained.

With the data obtained above, the corresponding hypotheses were contrasted, and the established statistical tests, such as the normality test, were performed. Table 8 shows the arithmetic means of each indicator in the pre and post-conditions.

In KPI-1, there was a reduction in symptoms, but in KPI-2, there was a considerable increase in feelings of realism. Finally, at KPI-3, there was a small increase in participants' BPM.

To contrast the pre and post KPI-1, we validated whether VR increases symptoms. Table 9 shows a quantitative summary of the pre and post-symptom rating scale of 50 students. VR did not increase symptoms in more than half of the participants.

Ha1 : The application of VR increases symptoms in users.
Where : Ho= P Value > 0.05
Ha= P Value < 0.05

Therefore, Ho, which represents the null hypothesis, indicates that if the p-value is greater than 0.05, both are equal, and there is no significant difference between the pre-test and post-test.

Table 9. KPI-1 Pre and Post-test contrast

Participant	KPI-1 Symptoms Pre	KPI-1 Symptoms Post
1	2.6	1.2
2	1.0	1.0
3	2.4	1.8
4	1.6	1.4
5	2.8	1.4
6	2.0	2.4
7	2.0	2.2
8	1.0	1.0
9	2.0	3.4
10	2.2	2.4
….	….	….
50	2.7	1.8

Table 10. Summary of the KPI-1 Pre and Post-Test contrast

	N	Media	Desv. Est.	Std. mean error
Pre-KPI-1	50	1.960	0.610	0.193
Post KPI-1	50	1.820	0.774	0.245
Difference	50	0.140	0.838	0.265
95% CI for mean difference: (-0.460; 0.740)				
Mean difference t-test = 0 (vs. ≠ 0): T-value = 0.53. p-value = 0.610				

Table 11. KPI-2 Pre and Post-Test contrast

Participant	KPI-2 Sensations Pre	KPI-2 Sensations Post
1	2.0	4.4
2	1.8	2.6
3	1.6	3.0
4	1.8	2.6
5	3.0	4.0
6	1.6	3.4
7	1.0	3.2
8	1.2	3.2
9	1.0	3.8
10	1.0	4.4
….	….	….
50	1.4	2.0

Table 12. Summary of the KPI-2 Pre and Post-Test contrast

	N	Media	Desv. Est.	Std. mean error
Pre-KPI-2	50	1.600	0.618	0.196
Post KPI-2	50	3.460	0.667	0.211
Difference	50	-1.860	0.875	0.277
95% CI for the mean difference: (-2.486; -1.234)				
Mean difference t-test = 0 (vs. ≠ 0): T-value = -6.73. p-value = 0.000				

Table 13. KPI-3 Pre and Post-Test contrast

Participant	KPI-3 BPM Pre	KPI-3 BPM Post
1	90	90
2	77	78
3	92	93
4	91	93
5	100	102
6	87	91
7	91	91
8	89	89
9	91	95
10	90	93
….	….	….
50	92	90

Table 14. Summary of KPI-3 Pre and Post-Test contrast

	N	Media	Desv. Est.	Std. mean error
Pre-KPI-3	10	90.80	5.96	1.88
Post KPI-3	10	91.50	5.97	1.89
Difference	10	-0.700	2.710	0.857
95% CI for the mean difference: (-2.639; -1.239)				
Mean difference t-test = 0 (vs. ≠ 0): t-value = 0.82. p-value = 0.435				

On the other hand, Ha, which represents the alternative hypothesis, indicates that if the p-value is less than 0.05, it automatically means that there is a significant difference between the pre-test and post-test, as shown in Table 10. This indicates that the proposed solution is effective and produces a change.

According to Table 10, the p-value obtained was 0.610, which indicates that the value is greater than 0.05. Therefore, this result shows that the null hypothesis is accepted, and the alternative hypothesis is rejected, resulting in the T-Student analysis not being significant.

Continuing with KPI-2, we validated whether VR increases realism feelings in participants by comparing them before and after the experiment.

Table 11 shows a quantitative summary of a symptom rating scale before and after the experiment, based on a sample of 50 students. A significant variation in favor of increased realism feelings in the participants can be observed.

Also, in Table 12, the mean, standard deviation, and statistical error of the mean of KPI-2, for the validation of Ha2: VR application increases the feeling of realism in VR in participants, are presented.

As a result of the T-Student test in Table 13, a p-value equal to 0.000 was obtained, indicating that the test was significant. As a final interpretation, the p-value obtained was 0.000, which indicates it is less than 0.05. Therefore, this result shows that the null hypothesis is rejected, and the alternative hypothesis is accepted, confirming the significance of the T-Student analysis. Finally, in KPI-3, the contrast between the pre-and post-tests was performed to validate whether VR increases BPM. Table 13 shows a numerical summary of the symptom rating scale of pre-and post-tests with a sample of 50 students. Also, Table 14 presents the mean, standard deviation, and statistical error of the KPI-3 mean to validate hypothesis Ha3: VR increases BPM.

As a result of the T-Student, Table 14 shows that the p-value is equal to 0.435, which means that the test was not significant. As a final interpretation, the p-value obtained was 0.435, which indicates that the value is greater than 0.05. Therefore, the result shows that the null hypothesis is accepted, and the alternative hypothesis is rejected, meaning the T-Student analysis was not significant. Claustrophobia is an anxiety disorder classified as a situational phobia. It is characterized by a fear of enclosed spaces and physical confinement, which can result in two types of fear: fear of suffocation and fear of confinement. In this research, experimental work with VR for claustrophobia was conducted. VR goggles, "Oculus Quest2," were used, which allow simulation of realistic scenarios in which the participant feels as if he/she is in a real elevator, as shown in Fig. 4 and 6.

he results of the research showed that the application of VR did not increase symptoms in the participants. However, applying VR presented more realistic sensations and failed to increase BPM during the experiment. These results correlate with the work done in the article [16], in which various VR-generated symptoms were obtained. In a very similar way to what was obtained in KPI-1, where it could be observed that various symptoms were generated, but without becoming significant. This indicates that VR generates symptoms when VR goggles are used. As in [17] and [18], in this research, BPM is used as a metric to measure the effectiveness of VR. It is also used to demonstrate signs of phobia in the participants. Furthermore, by examining the results of the article [19], it is shown that the degree of acceptance of VR as a tool for the treatment of claustrophobia has greater significance than the in vivo test. Therefore, it can be stated that VR is not considered aggressive but, on the contrary, very useful for this type of treatment.

5. Conclusion

Claustrophobia is characterized by an irrational fear of being in enclosed spaces. People who suffer from this disorder see their daily lives affected, and it is advisable to seek professional help; however, not all people have access to the necessary resources to go to a professional or follow an expensive treatment. This work presents an accessible solution for the treatment of claustrophobia: a VR application was developed for this purpose. Within the framework of this study, an experiment was conducted in which VR glasses "Oculus Quest 2" were used to recreate realistic and detailed environments, which succeeded in placing the participant within the developed scenario, specifically an elevator to simulate an enclosed space.

After the experiment, the results indicated that it failed to cause symptoms or raise the BPM (heart rate) significantly in the participants.

However, the VR application did manage to increase the sense of realism when wearing the VR goggles. It is important to note that if the participant is not minimally susceptible to the fear that is sought to be produced, it is very difficult for there to be variation in the metrics used, either in the symptoms generated during an anxiety attack or in the PBMs.

Therefore, in future work, it is recommended to develop different VR environments so that different claustrophobic scenarios are available and the most appropriate one can be found according to the participant's profile.

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