Virtual Reality as a Therapeutic Tool for Claustrophobia

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***Abstract* – This study addresses the growing need for innovative therapeutic tools in the treatment of specific phobias, particularly claustrophobia, which significantly affects quality of life. Previous research has demonstrated the effectiveness of virtual reality exposure therapy in anxiety-related disorders. The research question guiding this study was whether a virtual reality application (ClaustroVR) improves the treatment of claustrophobia symptoms. It was hypothesized that the application would significantly reduce average heart rate, anxiety subscale scores, and suffocation subscale scores. A quantitative, experimental design was employed with a non-probabilistic sample of 60 participants divided into experimental and control groups. Data were analyzed using the Mann–Whitney U test. Results showed statistically significant reductions in all three indicators in the experimental group (p < 0.05). These findings support the implementation of immersive virtual exposure as an effective complementary therapeutic tool for treating claustrophobia.**

***Keywords* – Virtual Reality, claustrophobia, exposure therapy, anxiety disorders, mental health.**

DOI: 10.18421/TEM153-17
https://doi.org/10.18421/TEM153-17

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Received: 12 August 2025.
Revised: 12 February 2026.
Accepted: 29 April 2026.
Published: 27 August 2026.

1. Introduction

A phobia is an intense fear that significantly impairs a person's ability to function in daily life, hindering their development by preventing them from performing regular activities [1]. Claustrophobia, characterized by the fear of enclosed spaces, affects approximately 12.5% of the global population and is more prevalent in women [2]. Within the spectrum of anxiety disorders, claustrophobia is recognized as a specific phobia according to the DSM-5 (diagnostic and statistical manual of mental disorders, fifth edition), which means it should receive the same clinical approach as other related disorders [3].

Anxiety is considered a natural response to a threat, but when it becomes disproportionate to the stimulus, it turns into a condition that seriously affects quality of life [4]. According to the World Health Organization, over 301 million people suffered from anxiety disorders in 2019, yet only 27.6% received treatment due to factors such as lack of awareness and insufficient investment in mental health services [5]. In the Peruvian context, EsSalud reported more than 182,000 cases of anxiety in 2024, highlighting a high prevalence among the elderly and children [6]. In regions like La Libertad, anxiety cases are closely linked to social, academic, and economic factors, mainly affecting adolescents [7].

Claustrophobia, in particular, manifests as an intense and immediate response to enclosed spaces, with symptoms ranging from mild discomfort to acute respiratory crises [3]. The most recommended therapeutic intervention is progressive exposure therapy, a technique based on cognitive-behavioral therapy (CBT), which consists of gradually exposing the patient to the feared stimulus until their emotional reaction is desensitized [8].

In this context, Virtual Reality (VR) has established itself as a viable tool. It allows for the controlled simulation of realistic environments, generating authentic emotional responses in patients and thus facilitating the therapeutic process [9].

According to [10], VR can even replace imagined exposure, offering advantages such as stimulus control, session repetition, and greater patient acceptance. However, there are technical limitations, such as equipment costs and certain side effects in patients with vestibular sensitivity or neurological conditions. Furthermore, research by [11] concludes that VR can be effective by enabling gradual and controlled exposure that helps reduce anxiety symptoms.

This leads to the research question: *How can a virtual reality application improve the treatment of claustrophobia symptoms?* This study aligns with sustainable development goal (SDG) 3 on health and well-being and proposes an innovative intervention using a virtual reality application designed to expose patients to claustrophobic virtual environments and evaluate its effects on three key indicators: Average heart rate, anxiety subscale score, and suffocation subscale score.

The general objective of the study was to improve the treatment of claustrophobia symptoms through the implementation of a virtual reality application. The specific objectives were: (a) To reduce the average heart rate values in patients, (b) To reduce the anxiety subscale score, (c) To reduce the suffocation subscale score.

The general hypothesis proposed that a virtual reality application improves the treatment of claustrophobia symptoms. The specific hypotheses were: (a) A virtual reality application reduces heart rate values in patients with claustrophobia symptoms, (b) A virtual reality application reduces the anxiety subscale score in patients with claustrophobia symptoms, (c) A virtual reality application reduces the suffocation subscale score in patients with claustrophobia symptoms.

2. Related Studies

This section presents key research that supports the present proposal, focusing on the application of VR as a therapeutic tool for the treatment of phobias and anxiety disorders. These studies have assessed variables such as anxiety levels, fear of specific stimuli, treatment adherence, and the effectiveness of exposure therapy, thus providing context for this study within the current scientific literature.

The pilot study by [12] evaluated the effectiveness of VR in adults with arachnophobia through therapist-assisted exposure. With a sample of 12 individuals, significant improvements were recorded in fear measures, with effect sizes ranging from $d = 0.90$ to $d = 1.384$, demonstrating a substantial decrease in fear following the intervention.

Meanwhile, [13] conducted a three-phase study with 107 students and 43 patients with depression. In all cases, exposure to VR significantly reduced anxiety. For example, 57% of those with moderate anxiety levels experienced a reduction after the session ($p < 0.05$), and both first- and third-person programs showed great effectiveness ($p < 0.001$), outperforming the control group.

The study by [14] implemented a therapy based on VR and mindfulness techniques in 25 adults with ADHD, compared to another group treated with medication. After four sessions, improvements were observed in anxiety symptoms, functionality, and quality of life, demonstrating that VR can be an effective and low-cost therapeutic alternative.

In the research by [15], the effects of VR exposure therapy (VRET) with and without rhythmic eye movements were evaluated in patients with arachnophobia. Although both groups improved, the difference was not significant ($p = 0.09$), highlighting that even without additional techniques, VR exposure had positive effects.

Additionally, [16] analyzed the effectiveness of VR exposure therapy in 186 patients with arachnophobia. Responders reduced their scores on the *spider phobia questionnaire* from 23.35 to 10.07, and avoidance distance from 177.06 cm to 72.07 cm. A total of 46% achieved remission, with greater success among those who responded favorably to the treatment (53.4%).

Moreover, [17] evaluated the app oVRcome with 126 individuals experiencing specific phobias. After six weeks, a significant reduction in symptom intensity was observed. The retention rate was 86.5%, indicating good acceptance and adherence to the treatment.

Finally, in Peru, [18] applied VR to 50 children undergoing venipuncture for blood extraction, showing that it significantly reduced pain ($X^2 = 43$; $p = 0.0000$) and anxiety ($X^2 = 38.33$; $p = 0.0000$). This highlights VR's usefulness as an accessible and effective tool, especially in low-resource hospital settings.

3. Theorical Framework

This section presents the theoretical foundations that explain the psychological mechanisms underlying claustrophobia and the conceptual basis for the use of Virtual Reality in therapeutic contexts.

3.1. Claustrophobia

Claustrophobia is a specific phobia characterized by an intense and persistent fear of closed or confined spaces. From a psychological perspective, this phobia is supported by various theories that explain its origin and maintenance.

According to the preparedness theory [19], humans are biologically predisposed to develop certain fears that posed evolutionary threats, such as enclosed spaces or darkness, thus facilitating anxiety responses to these stimuli.

Classical conditioning theory proposes that individuals learn to associate neutral stimuli with anxiety responses when these have been repeatedly paired with negative experiences [20]. For example, a person who has been trapped in an elevator may develop a phobic response to enclosed spaces due to the association between that environment and the traumatic event.

Last, the cognitive avoidance theory postulates that mental attempts to anticipate and solve problems can intensify anxiety symptoms [21]. By avoiding the feared stimulus, the individual reinforces the fear and perpetuates the anxiety cycle, contributing to the maintenance of the phobia.

3.2. Virtual Reality

The following subsection explains the theoretical and conceptual foundations supporting the use of Virtual Reality as an immersive therapeutic tool.

The use of VR as a therapeutic tool can be explained through conceptual frameworks that analyze the subjective experience of immersion and presence in simulated environments. One such foundation is the theory of possible worlds, which proposes that multiple conceivable realities exist, and VR allows some of these to be represented through interactive digital environments that emulate real experiences [22].

Additionally, social presence theory explores how digital interfaces influence the perception of presence in virtual environments [23]. This perception affects the realism of user interaction within these spaces, which is essential in therapeutic contexts where the virtual environment must evoke authentic emotions to facilitate exposure or confrontation processes.

3.3. Mobile-D Methodology

To develop the virtual reality application, the Mobile-D methodology was used, an agile approach specifically designed for software projects on mobile platforms. This methodology combines principles from extreme programming (XP) and Crystal Clear, allowing for iterative, flexible development cycles focused on continuous value delivery to the user.

Mobile-D is structured into five sequential phases: *Exploration*, where the product vision is defined; *Initialization*, which establishes the initial architecture and development environment; *Production*, focused on the progressive implementation of functionalities; *Stabilization*, involving testing and adjustments; and *Delivery*, which entails publishing or distributing the final product to the user [24].

4. Methodology

This section describes the research design, sample characteristics, data collection instruments, and statistical procedures employed in the study.

This study employed an applied research design with a quantitative approach and a pure experimental framework. A non-probabilistic sample of 60 people from a clinic in the city of Trujillo was used, divided into two groups of 30 participants each: One experimental group and one control group.

The intervention utilized A virtual reality application designed to treat symptoms of claustrophobia. Three main indicators were evaluated: The Average Heart Rate (AHR) as a physiological symptom, and the scores of the Anxiety Subscale (AScore) and the Suffocation Subscale (SScore) as emotional symptoms. Data collection was conducted through direct observation, a registration form, and two questionnaires validated by experts.

The results analysis included the Shapiro-Wilk normality test and hypothesis testing using the Mann-Whitney U test, due to the non-normal distribution of some data. Statistical processing was carried out using the Jamovi software.

Additionally, for the development of the virtual reality application called ClaustroVR, the agile Mobile-D methodology was used, designed for mobile software projects. This methodology consists of five phases: Exploration, Initialization, Production, Stabilization, and Delivery, and is based on agile development principles such as XP and Crystal.

During the Exploration phase, the project scope was defined, and key functionalities were identified. The system was developed in Unity 2022 using XR Interaction Toolkit for compatibility with Meta Quest 3. The experience was designed with two intensity levels: Light and Intermediate, comprising a total of four scenarios:

Light Level:

- Closed Room: Key search and walk through a narrow hallway,
- Children's Playground: Navigating hallways and activating an animated slide.

Intermediate Level:

- Automatic Boat: visual movement without manual control,
- Meadow and Cave: Entering a cave, collecting a flashlight, and searching for the exit.

Each scenario was designed with specific functionalities aligned with therapeutic goals, integrating mechanics such as object interaction, continuous locomotion, automated animations, and guided exploration.

The user-centered design considered physical and emotional limitations, allowing the experience to be adjusted based on the selected intensity level

The functional requirements defined for the ClaustroVR application are presented in Table 1.

Table 1. Functional requirements of the Virtual Reality application

Code	Name	Description
RF01	The game must have an intensity selector	The application allows the user to choose between the “Light” and “Intermediate” intensity levels.
RF02	The game must simulate 4 claustrophobic scenarios	The application enables the visualization of 4 different claustrophobic scenarios, 2 for each intensity level.
RF03	The game must allow interaction with objects	The application includes object interaction to progress through the scenarios.
RF04	The game must feature a virtual avatar	The application must include a virtual avatar that represents the user, allowing for greater immersion.
RF05	The game must record the duration of the therapy	The application includes a timer that starts when the intensity level is selected.

Table 1 presents the functional requirements of ClaustroVR. During the development phase, the team designed the key interfaces and mechanics of the application through iterative processes. The features defined included: Intensity selection (light and intermediate), simulation of four claustrophobic scenarios, object interaction, inclusion of a virtual avatar for greater immersion, and automatic recording of therapy duration. These functionalities were implemented to ensure a controlled and immersive therapeutic experience.

Continuing with the Initialization phase, material and human resources necessary for system development were organized. Unity 2022.3 LTS with XR Interaction Toolkit was used, along with Meta Quest 3 headsets, free and custom 3D models, and auxiliary software such as Blender. The team consisted of the lead developer (author of the thesis), a guiding therapist, and clinic staff who participated in the testing. The development environment was configured, and an iterative work schedule was established.

During the Production phase, five weekly iterations were executed, each focused on progressively developing the application’s core functionalities. The most relevant aspects addressed in each iteration are detailed below.

The development process was structured into five weekly iterations, as summarized in Table 2.

Table 2. Iteration table

Iteration	Description
Iteration 1	Implementation of the main menu with intensity selector (Light/Intermediate), XR Rig setup, and user interface configuration.
Iteration 2	Development of Scenario 1: Interaction with drawers, key search, door opening, and transition to the hallway.
Iteration 3	Development of Scenario 2: Exploration of the children’s playground area, activation of the slide, and transition to the end of the Light level.
Iteration 4	Development of Scenario 3: Automatic boat movement, visual journey through a mountainous environment, and final transition.
Iteration 5	Development of Scenario 4: Cave exploration, flashlight collection, lighting interaction, and exit. Implementation of the timer and results scene.

Throughout this phase, internal functional tests were conducted using the Meta Quest 3 headset, and technical details such as lighting, XR interaction, and narrative flow were adjusted accordingly.

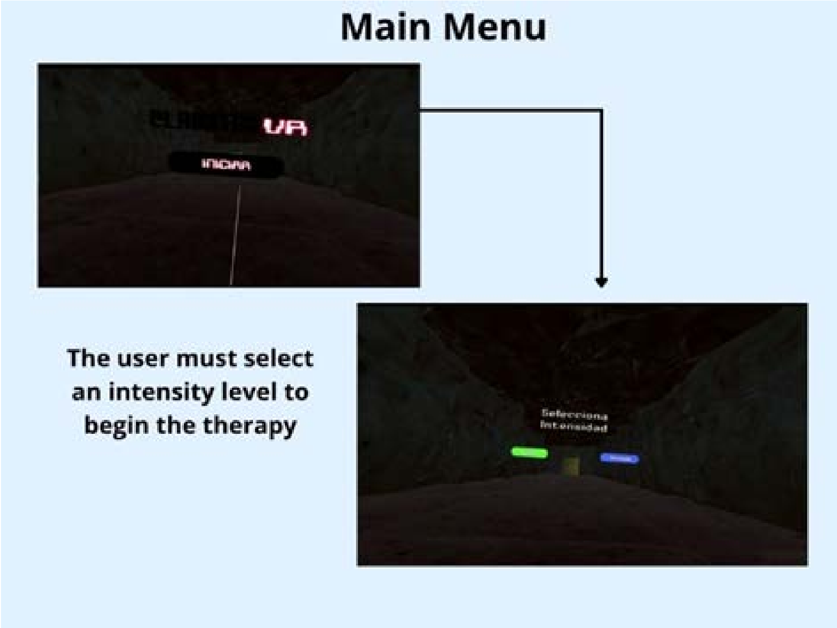

Figure 1. Main menu with intensity selector

As shown in Figure 1, the application's main menu was designed with a user-friendly interface that allows the user to select the intensity level: Light or Intermediate. This option determines which scenarios will be experienced during the exposure session.

In Figure 2, the scenarios corresponding to the Light level include a closed room with narrow hallways and a children's playground environment, where the user walks through a park and activates a slide.

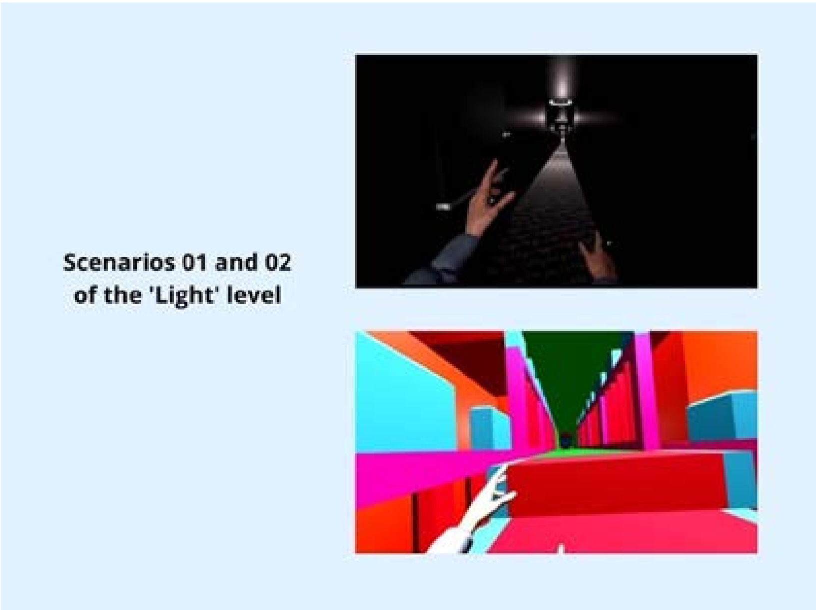

Figure 2. Scenarios 01 and 02 of the "Light" level

As shown in Figure 3, the Intermediate level scenarios are more intense:

The first simulates an automatic ride in a boat beneath a rocky formation, while the second introduces the user into a dark cave, where they must find a way out.

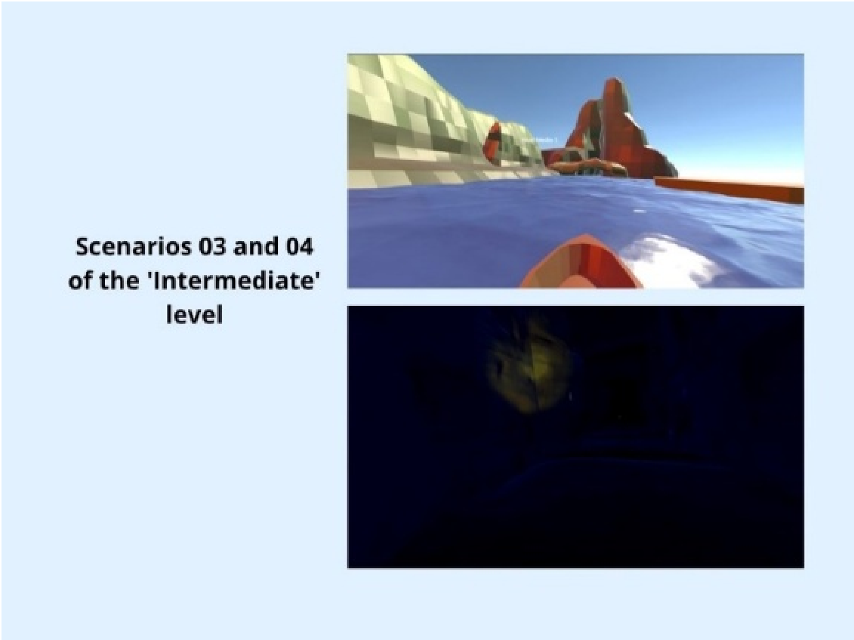

Figure 3. Scenarios 03 and 04 of the "intermediate" level

During the Stabilization phase, a series of technical tests and functional adjustments were conducted to ensure a smooth and stable immersive experience in virtual reality environments. The activities performed included correcting errors in collisions detected during user navigation, optimizing overall environment performance, and improving lighting to ensure proper spatial perception. Scene transitions were also carefully reviewed to ensure there were no interruptions or excessive loading times that could affect the continuity of the experience.

Additionally, adjustments were made to ambient sounds and visual effects to enhance sensory immersion without causing overload or discomfort to the user.

In the final development phase, functional system tests were conducted to validate the stability, user experience, and application compatibility in a real environment. These tests were carried out between April 28 and May 6, 2025, in a psychological clinic, with real patients participating under the supervision of a mental health professional.

During this phase, key aspects were evaluated such as scene navigation, accuracy of interactions (like collecting keys and flashlights), animation fluency, and the compatibility of the application with the Meta Quest 3 headset.

The results were positive: Participants adapted well to the virtual environments, reported no severe discomfort, and responded appropriately to gradual exposure stimuli in the different scenarios. As a result, the application was deemed functional and stable under real conditions, having been validated through direct observation in a controlled clinical environment.

5. Results

This section presents the descriptive and inferential analyses for each of the studied indicators to determine whether the proposed hypothesis is accepted or rejected.

5.1. Descriptive Analysis

The results of the descriptive analysis are presented grouped by type of indicator: The quantitative average heart rate (AHR) and the qualitative indicators anxiety subscale score (AScore) and suffocation subscale score (SScore). In the first case, averages between groups are compared, while in the other two, the severity levels of recorded symptoms by category are analyzed.

The descriptive results for the average heart rate indicator are summarized in Table 3.

Table 3. Summary of the average heart rate (AHR) indicator

Indicator	Avg. CG	Avg. EG	%EG < Own Avg.	% EG < Target (65)	% EG < Avg. CG
AHR	84.0	76.4	56.67%	16.67%	76.67%

As shown in Table 3, 76.67% of the Experimental Group (EG) achieved a heart rate lower than the average of the Control Group (CG). Additionally, 56.67% of the EG had values below their own average, and 16.67% were below the established target of 65 bpm.

The distribution of anxiety and suffocation levels between the control and experimental groups is summarized in Table 4.

Table 4. Summary of AScore and SScore indicator

Indicator	Level	Frequency		% Total	
		CG	EG	CG	EG
AScore	Low	0	10	0%	33.3%
	Moderate	1	18	3.3%	60%
	High	19	2	63.3%	6.7%
	Very High	10	0	33.3%	0%
SScore	Low	0	10	0%	33.3%
	Moderate	3	15	10%	50%
	High	16	5	53.3%	16.7%
	Very High	11	0	36.7%	0%

Table 4 shows that, in the experimental group, 93.3% of participants were in low or moderate anxiety levels (AScore), compared to the control group, where 96.6% were in high or very high levels. Likewise, for the SScore indicator, 83.3% of the experimental group showed low or moderate levels of suffocation perception, compared to 90% of the control group in high or very high levels. These results suggest a positive impact of the Virtual Reality intervention in reducing emotional and physiological symptoms associated with claustrophobia.

5.2. Inferential Analysis

The inferential analysis consisted of two stages: The Shapiro-Wilk normality test and the hypothesis testing, to evaluate whether there were statistically significant differences between the Control Group and the Experimental Group in the following indicators: Average heart rate, anxiety subscale score, and suffocation subscale score.

The Shapiro-Wilk test was employed due to the sample size being less than 50. The decision criteria were as follows:

- If $p < 0.05$, H_0 is rejected (data do not follow a normal distribution).
- If $p \geq 0.05$, H_0 is accepted (data follow a normal distribution).

The results of the Shapiro-Wilk normality test are presented in Table 5.

Table 5. Shapiro-Wilk test results for the three indicators

Indicator	CG	EG	Distribution
AHR	0.004	0.207	Non-normal / Normal
AScore	0.307	0.293	Normal / non-normal
SScore	0.002	0.241	Non normal /non-normal

According to Table 5, in all cases, at least one of the groups did not meet the normality assumption such as the EG in the AScore indicator, where the distribution was not normal therefore, the non-parametric Mann-Whitney U test was utilized to compare differences between the groups.

The results of the Mann–Whitney U test for the three evaluated indicators are presented in Table 6.

Table 6. Mann-Whitney U test results for the three indicators

Indicator	U Statistic	p value	Interpretation
AHR	301	0.014	Significant
AScore	36	<0.001	Significant
SScore	51	<0.001	Significant

As shown in Table 6, the p-values for all three indicators were less than 0.05, providing sufficient statistical evidence to reject the null hypothesis (H_0) and accept the alternative hypothesis (H_a). This confirms that the virtual reality application had a significant effect in reducing average heart rate, anxiety score, and suffocation score in the experimental group.

6. Discussion

This section analyzes the impact of the virtual reality application ClaustroVR on improving the treatment of symptoms associated with claustrophobia. The discussion is based on the results obtained for the three main indicators: Average heart rate, anxiety subscale score, and suffocation subscale score, comparing data from the experimental and control groups and situating these findings within the framework of prior research in the field of virtual reality applied to mental health.

The results for the first specific objective show that 76.67% of the experimental group (EG) achieved a heart rate lower than the average of the control group (84 bpm), while 56.67% were below their own group average (76 bpm), and 16.67% achieved values below the therapeutic threshold of 65 bpm. Overall, the EG showed a reduction of 7.6 bpm compared to the CG, representing a 9.05% decrease.

This finding can be compared to the study by [15], which evaluated the efficacy of rhythmic eye movements (EM group) during virtual exposure in patients with arachnophobia. In that study, the EM group had an average heart rate of 86.47 bpm, compared to 92.70 bpm in the control group, a reduction of 6.23 bpm (6.71%). Although this study did not include complementary techniques like eye movements, the results show an even greater reduction, suggesting that the progressive immersive design of ClaustroVR was effective in eliciting an adaptive physiological response.

Regarding the second specific objective, reducing the anxiety subscale score, it was found that 93.3% of the EG had low or moderate anxiety levels (60% moderate and 33.3% low), whereas in the CG, 96.6% of participants showed high (63.3%) or very high (33.3%) anxiety levels. This difference was statistically significant ($p < .001$). This finding is consistent with the study by [13], where it is reported that after a single session of VR exposure, 57% of participants with moderate anxiety reduced their level, and both first- and third-person programs significantly reduced situational anxiety ($T\ exp \leq 1.0$; $p < .001$). Although that study does not provide the same level of detail in percentage changes, the current data show a more pronounced shift in overall anxiety distribution, from 0% low anxiety in CG to 33.3% in EG, and from 3.3% moderate in CG to 60% in EG, demonstrating the effectiveness of ClaustroVR's controlled immersive environment in reducing anxiety triggered by claustrophobic settings.

As for the third objective, reducing the suffocation subscale score, it was found that 83.3% of the EG were at low or moderate suffocation levels, while 90% of the CG were at high or very high levels. This result was also statistically significant ($p < .001$). These findings align with the results obtained by [16], who in their research on arachnophobia found an average reduction of 13.28 points in the spider phobia questionnaire (SPQ), from 23.35 to 10.07, representing a 56.9% decrease. Furthermore, patients improved on the behavioral avoidance test (BAT), reducing their avoidance distance from 177.06 cm to 72.07 cm, reflecting a notable behavioral change. Although the phobia studied was different, the therapeutic mechanism employed (immersive exposure via VR) is the same, allowing for a valid analogy. The reduction in perceived suffocation observed with ClaustroVR reinforces its therapeutic utility for treating intense symptoms associated with confined spaces, such as in claustrophobia.

A notable difference from previous studies is that ClaustroVR was not utilized in prolonged sessions or with constant therapist accompaniment, as is common in more clinical settings.

Nevertheless, the observed effects were significant, which may be attributed to an effective immersive design and adequate patient preparation prior to the experience. This contrasts with the study by [17], who developed the oVRcome app, combining self-guided VR exposure with cognitive behavioral therapy over six weeks. Their study included 126 participants and achieved a retention rate of 86.5%, reporting significant reductions in symptoms of specific phobias. Unlike that structured and progressive approach, ClaustroVR was applied in a single exposure session, which highlights the effectiveness of its design even with limited interventions and suggests that brief treatments can generate clinically relevant effects when the virtual environment is well-designed.

During the execution of this research, the following methodological limitations were identified:

First, there was difficulty adapting among individuals over 50 years old, who reported discomfort and nervousness when using the VR headset, although this did not prevent their participation.

Second, minors were excluded for ethical reasons, which limited the generalizability of the results.

One of the strengths of this study was the use of a pure experimental design with control and experimental groups, which allowed for a clear isolation of the effect of ClaustroVR. Additionally, the inclusion of validated instruments and the combination of objective measures (heart rate) with subjective measures (clinical anxiety and suffocation questionnaires) provided a comprehensive view of the changes generated by exposure to virtual environments, offering solid evidence for the field of technology-assisted mental health.

In the future, it is recommended that ClaustroVR be adapted for supervised clinical environments and eventually scaled as a mobile application for self-guided sessions. Moreover, this approach could be extended to other specific phobias and vulnerable populations, such as children or older adults, as long as appropriate technological and ethical adaptations are considered.

7. Conclusion

The results demonstrated statistically significant improvements in all indicators of the experimental group compared to the control group, thereby supporting the effectiveness of the proposed treatment.

Regarding the physiological indicator (AHR), 76.67% of participants in the experimental group had values below the control group average (84 bpm), and 56.67% were below their own group average (76 bpm), indicating a reduction in physiological activation in response to the claustrophobic stimulus.

As for the AScore, 93.3% of experimental participants reached low or moderate anxiety levels, compared to 96.6% of the control group who remained at high or very high levels.

Finally, for the SScore, 83.3% of the experimental group were in low or moderate levels of suffocation perception, while 90% of the control group remained in high or very high levels.

These findings, validated through the Mann-Whitney U test with p-values below 0.05, confirm the positive impact of immersive virtual exposure on reducing the physiological and emotional symptoms associated with claustrophobia.

Based on the findings and considering the identified methodological limitations, the following recommendations are proposed for mental health professionals and institutions interested in implementing virtual reality exposure therapies for the treatment of specific phobias such as claustrophobia.

First, it is recommended to begin implementing VR therapies with young or middle-aged adults up to 50 years old. This suggestion is based on observations during the study, where older individuals experienced more difficulty adapting to the VR headset, reporting discomfort or additional anxiety. These reactions may interfere with the effectiveness of the intervention; therefore, careful participant selection is advised in early implementation stages.

Second, although this study was limited to a single exposure session per patient, future applications should include multiple sessions supervised by a clinical psychology professional. Based on expert recommendations, the best outcomes in treating specific phobias are achieved through progressive exposure, so it is suggested to design protocols of at least three to five sessions, tailored to each patient's individual progress.

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