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Combinated Virtual Reality Exposure and Biofeedback in Acrophobia Treatment

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Abstract

Acrophobia is the most prevalent type of specific phobia, and it is defined according to DSM V as an extreme fear of heights. It is a chronic disorder that may impact people's lives. The most common therapy used in this condition is cognitive behavior therapy (CBT). This therapy aims to modify non-adaptive cognitions and behaviors, challenging dysfunctional thoughts and beliefs through cognitive and behavioral strategies, including, for example, cognitive restructuring and exposure. Through Virtual Reality, as an exposure therapy, it is possible to obtain a more assertive control of the therapeutic environment, facilitating adaptability and problem solving and offering greater possibilities for customization, flexibility, and control of the therapeutic process.

This intervention will consist of 16 biweekly evolutions (8 weeks), with each session lasting 50 minutes and structured as follows: Preparation and warm-up of the participant; Personalized and progressive exposure to virtual environments of systematic desensitization; Relaxation and Feedback.

The results from both self-report and psychophysiological data revealed a significant reduction in fear of heights in the participants exposed to the exposure therapy program, showing a positive impact of this protocol on the treatment of Acrophobia.

Keywords: Anxiety Disorders, Acrophobia, Exposure Therapy, Virtual Reality, Biofeedback, Cognitive Behavioral Therapy.

Índice

1. Introduction

Specific phobia is the most prevalent of the anxiety conditions. It is characterized as an extreme fear or anxiety in the presence of a particular situation or object, called a "phobic stimulus" (5–11). Being the female gender affected three times more than the male gender, the subcategory of specific phobias has not been well studied, perhaps due to individuals with specific phobias who do not always seek treatment (1).

Acrophobia is the most prevalent type of specific phobia (2), and it is defined according to DSM V as an extreme fear of heights (3). It is a chronic disorder that may impact people's lives (4).

People with acrophobia tend to avoid situations that cause them suffering and anxiety, such as riding an elevator, climbing stairs, flying, walking on bridges, or even approaching windows (5). That fear causes stress, and this stress reduces their quality of life (5). One-third of the population is susceptible to develop acrophobia (5).

The National Institute for Health and Care Excellence (NICE) and the Canadian Psychiatric Association presents evidence-based clinical guidelines that allow reliable recommendations regarding approaches that should be taken in various health conditions (6). NICE guidelines recommend using cognitive-behavioral therapy instead of drug therapy for anxiety disorders, while the Canadian Psychiatric Association considers both first-line pharmacological and non-pharmacological treatments (6). Both psychotherapy and pharmacotherapy should be offered (1).

The most common therapy used in this condition is cognitive behavior therapy (CBT), (7–11). This therapy aims to modify non-adaptive cognitions and behaviors, challenging dysfunctional thoughts and beliefs through cognitive and behavioral strategies, including, for example, cognitive restructuring and exposure (7–11).

The participants must be informed about their disorder and treatment choices, aggravating factors, and signs of relapse (12).

Meta-analyses have shown the efficacy of psychological treatments in group and individual formats, in patients with specific phobia, particularly exposure therapy and other cognitive behavioral therapy (CBT) protocols (12).

CBT includes essentially desensitization therapy, exposure therapy in vivo, exposure therapy using virtual reality, applied relaxation, cognitive-behavioral therapy, training of social skills,

cognitive restructuring, mindfulness, and drug therapy in association or not with one of the previous interventions (1,7,15,16,8,8–14).

For the treatment of Acrophobia, several therapeutic approaches are applied. The most commonly used is desensitization therapy, in vivo exposure therapy, virtual reality exposure therapy, and drug therapy combined with one of the previous interventions (15).
Desensitization therapy trains self-control and relaxation methods and slowly exposes them to simulated fearful situations (17). In vivo exposure therapy exposes clients to real-world height scenarios while maintaining their anxiety at controlled levels (17,18).
Exposure therapy is the current treatment chosen for specific phobias (1,7,15,16,8,8–14). The standard form of exposure therapy involves in-vivo or imaging approaches to phobic stimuli or situations. Virtual-reality exposure therapy was first introduced more than two decades ago to treat fear of heights. Virtual reality exposure therapy exposes clients to computer-generated height scenarios while maintaining their anxiety at controlled levels (1,7,15,16,8,8–14).

About the psychophysiological measures, dysregulation in autonomic nervous system activity often provides biomarkers for anxiety like fast, irregular heart rate, increased heart rate variability, respiratory variability and warm skin temperature due to increased vasodilation (19–24).

Psychophysiological arousal indicates the activation of the fear structure in the brain and, the habituation during exposure therapy is seen as an indicator of successful changes in that structure. So, encouraging participants to experience fear and its symptoms during exposure therapy is common practice and is a combination of biofeedback and CBT (23,24)
Duff, Miller & Bruce (25) studied the effects of using Virtual Reality (VR) as a therapeutic method compared to in vivo exposure therapy methods. He concluded that these approaches have more positive results. Through Virtual Reality, it is possible to obtain a more assertive control of the therapeutic environment, facilitating adaptability and problem solving and offering greater possibilities for customization, flexibility, and control of the therapeutic process (2,24,26–30).
VR can produce therapeutically helpful scenarios if used in the right way but nearly impossible to recreate in real life (30,31). In addition to environmental control, Virtual Reality also allows the achievement of a very high degree of confidentiality, as exposure is made within a room, and there is no risk of potential negative reactions from either the individual or possible observers

(30–32). Individuals can enter simulations of difficult situations and be coached to the appropriate responses (31). Those simulations can be graded in difficulty and repeatedly experienced (31).

Whatever the limits the real world imposes on us, the virtual world is ideal because it allows unlimited reflections and creates a space where the impossible becomes possible. Modern technological solutions generate a new reality that can be used in many areas of daily life (30). Individuals know that the virtual environment is not real. Still, their minds and bodies behave as if they were real, so it will be easier to face phobic situations in VR and experiment with new therapeutic strategies (31). In that way, they learn it can be transferred to everyday life (31).

This type of exposure seems to be very effective in the individual's controlled and personalized systematic desensitization regarding the phobic stimulus and related impulsive responses, enhancing emotional self-regulation and associated cognitive restructuring (24,26,29,30,32–34).

This study tested de effectiveness of an intervention based on Virtual Reality in the treatment of acrophobia.

1. Methods

1.1. Participants

Through the non-probabilistic convenience technique, as individuals voluntarily agreed to participate in the study, they were selected according to our inclusion criteria and more accessible contact.

Inclusion criteria to participate in the study were fear of heights (at least 2 on the Likert scale when asked about the fear of being on a second-floor balcony, leaning against a 1-meter high parapet), motivation, and willingness to participate in the study and to go twice a week to LabRP / ESS.PPORTO facilities. Exclusion criteria were individuals with health problems that should avoid exposure to Virtual Reality, namely labyrinthitis.

The privacy and confidentiality of the collected data were also attested. The study was approved by the Ethics Committee of the School of Health, Polytechnic of Porto (CE0017B). The study was formalized by completing the informed consent form (35) to ensure their rights and access to all information relevant to the decision to participate in the study.

1.2. Instruments

Clinical Interview: Built to collect sociodemographic information and survey brief to clinical history related to fear of heights and other conditions contraindicated exposure to Virtual Reality. The semi-structured interview guide consisted of five questions related to sociodemographic data and seven open-ended questions.

Simulator Sickness Questionnaire (SSQ): Applied to assess the presence of cybersickness. Also, according to a Likert scale with 1 corresponding to "totally disagree" and 5 "totally agree" (total 55). When faced with higher values, it indicates more adverse reactions to VR (36).

Sense of Presence Inventory (ISP): Applied to evaluate the Virtual Reality experience, to understand the interaction with the environment. Also, according to a Likert scale with 1 corresponding to "totally disagree" and 5 "totally agree" (total 70). When faced with higher values, it indicates more immersive.

Behavioral Avoidance Test (BAT): Divided into two parts, one applied before in vivo exposure and the other applied after it; in both moments, the participants had to report their level of fear, anxiety, and danger felt for each situation (a second-floor balcony – exposure to 5 meters or 10 meters), on a Likert scale from 0 to 10 (total 60). When faced with higher values, it indicates more adverse reactions to heights.

Acrophobia Questionnaire: Split into two parts with various situations that can trigger anxiety due to fear of heights. The first part concerns he levels of fear that the participant feels in each situation and, therefore, must answer from 0 to 6 regarding the fear they would feel in those same situations (total 120). When faced with higher values, it indicates more anxiety. The second part is related to avoidance in the same situations, with the participant answering how much he avoided each of the situations, on a Likert scale from 0 to 2 (total 40). Again, when faced with higher values, it indicates more avoidance.

Psychophysiological Procedures: To collect physiological parameters that would allow the use of the biofeedback principles among the participants, the Biopac MP160 device connected to a Bionomadix 2-channel wireless system was used to obtain heart rate from the Peripheral pulse signal (lead I), Respiratory rate (lead II) and Electrodermal activity (EDA) (lead III). These data were

recorded during exposure in all the therapeutic sessions and were used to demonstrate to individuals their evolution over therapeutic intervention.

1.3. Procedures

This intervention will consist of 16 biweekly evolutions (8 weeks), with each session lasting 50 minutes and structured as follows: Preparation and warm-up of the participant; Personalized and progressive exposure to virtual environments of systematic desensitization; Relaxation and Feedback. Therefore, this treatment strategy consists of a combination of therapeutic ingredients, which includes exposure to fear-triggering stimuli, therapeutic instructions, monitoring client progress, performance feedback, and contingent performance enhancement. The intervention focuses on shaping the trend of preference through a process of successive approximations. Treatment is achieved by reducing the avoidance of the feared situation if the absence of consequences will result in the extinction of fear, a common ingredient of exposure therapies. The performance of the evolution behavior will be facilitated, reinforcing the approximations and removing the negative reinforcement of avoidance. The graduation of the exhibition can be based on an amount of time (between 15–30 minutes) or several practices with different levels of complexity and intensity. Immersion and presence in the virtual environment (Richie's Plank, not included) are achieved using HTV Vive Pro virtual reality glasses.

Regarding the procedures for analyzing and processing the empirical information collected, the IBM SPSS Statistics 27 software was used (37). In terms of sociodemographic characterization of the study participants, descriptive statistics were used. Considering the variables used, the mean and mode were calculated as a measure of central tendency, the standard deviation as a measure of dispersion, and the absolute frequencies and frequency of each characteristic under analysis. Regarding the verification of significant changes before and after implementing the intervention protocol, inferential statistical analysis procedures were mobilized, assuming for all statistical tests used a significance value (α) of 0.05 (38–40). In addition, the normality, the homogeneity and the sphericity of the variables were assumed.

2. Results

In general, our sample had thirty-one participants, divided into control and experimental groups. As described in Table 1, most of this group consisted of females (64,5%), single (87,1%), with high

school (61,3%), and who never had any consumption of substances such as psychoactive drugs (96,8%). In addition, 67,7% never had psychological treatment, and only 22,6% are currently undergoing treatment. Of those who have already undergone psychological treatment, 25,8% were related to fear of heights.

Fifteen subjects participated in this study in an experimental group (n=15). As described in Table 1, most of this group consisted of females (53,3%), single (86,7%), with high school (53,3%), and who never had any kind of consumption of substances such as psychoactive drugs (100%). In addition, 53,3% never had psychological treatment, and only 26,7% are currently undergoing treatment. Of those who have already undergone psychological treatment, 40% were related to fear of heights.

In a control group, sixteen subjects participated in this study (n=16). As described in Table 1, most of this group consisted of females (75%), single (87,5%), with high school (68,8%), and who never had any consumption of substances such as psychoactive drugs (87,5%). In addition, 81,3% never had psychological treatment, and only 18,8% are currently undergoing treatment. Of those who have already undergone psychological treatment, 12,5% were related to fear of heights.

Tabela 1 – Characterization of the sample divided by groups regarding the sociodemographic data

	Sample		**Experimental**		**Control**	
	N=31		N=15		N=16	
	x/s	**min.-máx**	**x/s**	**min-máx**	**x/s**	**min-máx**
Age (years)	25,06±9,93	18-67	24,67±6,86	19-45	25,44±12,42	18-67
	Mode (%)		**Mode (%)**		**Mode (%)**	
Gender	Female (64,5%)		Female (53,3%)		Female (75%)	
Marital Status	Single (87,1%)		Single (86,7%)		Single (87,5%)	
School Grade	High school (61,3%)		High school (53,3%)		High school (68,8%)	
Treat. Psychological	No (67,7%)		No (53,3%)		No (81,3)	
Dependency History	No (96,8%)		No (93,3%)		No (100%)	
Current Consumption	No (93,5%)		No (100%)		No (87,5%)	

N- Absolute frequency; % - Relative frequency; x - average; s - standard deviation

2.1. Virtual Reality Questionnaires

Through repeated measures ANOVA, there are significant differences between at least two population means regarding the Simulator Sickness Questionnaire. Applying the Post Hoc test, we can conclude that the pre-test values are significantly different from the post-test values in at least one of the groups (p=0.002). Through MANOVA, we can conclude that the differences observed between the two moments in the experimental group are highly significant (p=0.01) and that the differences observed between the two moments in the control group are not statistically significant (p=0.06) (Table 2).

Through repeated measures ANOVA, regarding the Sense of Presence Inventory, there are significant differences between two population means. Applying the Post Hoc test, we can conclude that the values of the groups are significantly different at least in one moment (p=0.0001). Through MANOVA, we can conclude that the differences observed between the two moments in the two groups are highly significant (p=0.0001) (Table 2).

Tabela 2 – Summary statistical measures for the pre and post-test Simulator Sickness Questionnaire and Sense of Presence Inventory in the control and experimental groups

		Pre- Test x/s	Post- Test x/s	p(value)
Simulator Sickness Questionnaire (SSQ)	Control Group	33,75±12,54	29,13±10,92	0,55
	Experimental Group	34,20±8,96	27,53±9,61	
	p(value)	0,002		
Sense of Presence Inventory (ISP)	Control Group	54,44±6,99	48,69±6,29	0,13
	Experimental Group	56,07±6,08	47,87±4,44	
	p(value)	0,0001		

x - average; s - standard deviation

2.2. Acrophobia Questionnaires

Regarding the Behavioral Avoidance Test, there are significant differences between the two assessment moments, which depend on the group. Therefore, we can conclude that the group has a significant effect on the evaluation moments. Applying the Post Hoc test, the pre-test

values are significantly different from the post-test values in at least one of the groups (p=0.0001). Using Manova, we can conclude that the differences observed between the two-time points in the experimental group are highly significant (p=0.0001) and that the differences observed between the two-time points in the control group are not statistically significant (p=0.9) (Table 3).

Through repeated measures ANOVA, regarding the Acrophobia Questionnaire, there are no significant differences between the two evaluation moments, and they are not group dependent (Table 3).

Tabela 3 – Summary statistical measures for the pre and post-test Acrophobia Questionnaire and Behavioral Avoidance Test in the control and experimental groups

		Pre- Test x/s	Post- Test x/s	p(value)
Behavioral Avoidance Test (BAT)	Control Group	28,44±11,05	28,19±15,65	0,001
	Experimental Group	36,53±8,92	12,93±11,13	
	p(value)	0,001		
Questionnaire of Acrophobia Anxiety	Control Group	43,06±26,22	45,56±28,32	0,12
	Experimental Group	46,73±29,29	33,60±23,97	
	p(value)	0,26		
Questionnaire of Acrophobia Avoidance	Control Group	12,01±7,95	10,88±8,19	0,37
	Experimental Group	9,67±7,23	6,40±5,51	
	p(value)	0,07		

x - average; s - standard deviation

2.3. Psychophysiologic Procedures

Through repeated measures ANOVA, regarding the Respiratory frequency Average and Cardiac frequency Average, there are no significant differences between the two evaluation moments, and they are not group dependent (Table 4).

Regarding Electrodermal activity Amplitude, there are significant differences between the two evaluation moments. Applying the Post Hoc test, we can conclude that the pre-test values are significantly different from the post-test values in at least one of the groups (p=0.02).

Furthermore, the control group values are significantly different from the experimental group values (p=0.04). Using Manova, we can conclude that the differences observed between the two-time points in the experimental group are highly significant (p=0.007) and that the differences observed between the two-time points in the control group are not statistically significant (p=0.66) (Table 4).

Regarding Electrodermal activity, skin conductance responses (SCRs), there are significant differences between the two evaluation moments. Applying the Post Hoc test, we can conclude that the pre-test values are significantly different from the post-test values in at least one of the groups (p=0.0001). Using Manova, we can conclude that the differences observed between the two-time points in the experimental group are highly significant (p=0.0001) and that the differences observed between the two-time points in the control group are not statistically significant (p=0.99) (Table 4).

Tabela 4 – Summary statistical measures of pre and post-test, control, and experimental Psychophysiological Procedures

		Pre- Test x/s	**Post- Test x/s**	**p(value)**
Respiratory frequency Average	Control Group	18,63±0,62	18,31±0,95	0,22
	Experimental Group	18,60±0,91	16,73±4,73	
	p(value)	0,16		
Cardiac frequency Average	Control Group	176,9±0,77	176,5±1,67	0,22
	Experimental Group	176,13±1,30	169,47±19,92	
	p(value)	0,09		
Electrodermal activity Amplitude	Control Group	0,0016±0,001	0,0002±0,001	0,08
	Experimental Group	0,0015±0,001	0,0007±0,001	
	p(value)	0,02		
Electrodermal activity SCRs	Control Group	2195,9±1690,9	2200,2±1957,3	0,001
	Experimental Group	2741,5±1401,8	102,33±165,8	

	p(value)	0,001

x - average; s - standard deviation

3. Discussion

The results obtained through the *Simulator Sickness Questionnaire* indicate that adverse reactions to exposure to Virtual Reality are reduced with prolonged exposure since the values of the experimental group decreased significantly when comparing the pre-test with the post-test. In the experimental group's post-test, we obtained a total score of 27.53 points out of 55 points, which indicates few adverse reactions to exposure. Although it did not show significant differences, the control group also had a low score, indicating that it also had few adverse reactions (41).

It is important to note that the questions with the highest scores are those related to increased sweating and dizziness, which may be related to fear of heights and not exposure to a virtual environment since these are common reactions in individuals with Acrophobia (19–24).

The results obtained can be justified by habituation to the equipment and the environment due to prolonged exposure. In addition, studies indicate that the quality of the equipment can influence the more or less intense presence of these reactions. However, there are also references that increased presence and immersion can lead to increased adverse reactions because these reactions are related to the difference between what the vision and the body perceive (42–46).

In this regard, we assessed participants' presence in the virtual environment using the *Sense of Presence Inventory*. Presence, in this context, is defined as the subjective feeling of being somewhere else and is a crucial element in exposure-based therapies (24). Furthermore, the sense of presence is conditioned by the degree of immersion that each technology and virtual environment can offer (43).

In the present study, the feeling of presence decreased from the pre-test to the post-test, which can also be explained by the habituation to the equipment and the environment. The reduction in scores occurred in both groups, with a slightly higher reduction in the experimental group. It is important to note that the scores are not considered low, which suggests a high presence in the simulated context and consequent immersive.

High presence values can also be associated with using the Cave Automatic Virtual Environment (CAVE), a virtual, immersive, and interactive environment. The CAVE system is based on a cube-shaped room where videos and virtual representations are projected onto the walls. Virtual reality glasses are used with sound, and the room itself contains elements inherent to the virtual environment, in this case, the wooden board, which increases the immersive (34,43).

Studies also indicate that there may be an association between presence levels and the positive effects of exposure as a therapeutic technique (34,42,43).

The Behavioral Avoidance Test (BAT) results also seem to show a positive evolution regarding the fear of heights reported by the study participants since there was a significant decrease in the score of the experimental group. In this questionnaire, the maximum score is 60, which corresponds to high fear of heights, anxiety when exposed to an environment with heights, and danger in that same place. On the other hand, the score obtained by the experimental group in the post-test was 12.93, which shows low levels of fear, anxiety, and feeling of danger. These results contribute to evidence of a positive effect of the program in the treatment of fear of heights.

The results obtained with the *Acrophobia Questionnaire* did not show significant changes from pre-test to post-test, although the mean score in the experimental group decreased. This reduction in score suggests that this Exposure Therapy protocol using Virtual Reality had a positive effect on reducing the anxiety level of participants in the experimental group regarding situations of exposure to heights. Concerning avoidance, both groups showed a reduction in the score. Ainda que o score final deste questionário não reproduza diretamente o nível de Acrofobia do sujeito, a sua variação entre o pré- e pós-teste pode ser utilizado para analisar a perceção do sujeito relativamente ao medo a alturas, dado que valores elevados do score, corresponderão a níveis maiores de receio e ansiedade desencadeados pelas situações bem como o evitamento das mesmas (47,48).

The analysis of this questionnaire also allows us to conclude that, although the participants in this study felt anxious about the mentioned contexts, they showed little avoidance reaction to them. Furthermore, this avoidance also decreased after the application of the program.

The fact that the values did not reduce significantly may be associated with the fact that this questionnaire is self-report and based on the individual's perception, not being applied in context.

A more reliable way to assess anxiety levels associated with height environments is the psychophysiological analysis.

To detect a person's level of mental stress, various biosignals are measured. The Cardiac frequency, combined with Galvanic skin response, is the most widely used methodologies to investigate the relationship between human behavior and its physiological basis (49–51).

In terms of *Respiratory frequency*, there were no significant differences. Despite this, the mean in the experimental group decreased slightly, which suggests a slight reduction in anxiety levels. Low respiratory frequency values seem to be related to respiratory apneas, as reported in several studies that concluded that individuals faced with fearful situations suffer respiratory apneas (50). The fact that there were no significant decreases in the values may indicate fewer moments of apneas and thus more control of anxiety levels by participants in the experimental group. It is important to note that the values presented are within normal values (10–20rpm) (52).

As far as the values verified in the *Cardiac frequency* is concerned, it is relevant to emphasize that the exposure to the virtual environment that evaluates the fear of heights in the post-test generated lower values in the experimental group than in the control group. However, there were no statistically significant differences. It is also relevant to mention that the values recorded are too high for normal (60–100bpm), which shows that the participants were exposed to an anxiety-producing situation (51).

Anyway, the heart rate and respiratory rate values were slightly reduced from pre-test to post-test in the participants who participated in the experimental group, pointing to a possible positive effect of the program in reducing anxiety and fear of heights.

One way to analyze EDA is through the SCRs observed in the temporal window of interest, for example, the frequency or total amplitude of the SCRs. The SCRs reflect the highest frequency variability of the whole signal (53). In the present study, both the amplitude and the number of SCRs were significantly different between the pre and post-test, reducing stressful reactions during exposure. These results may mean that the protocol under study led to a decrease in anxiety on exposure to heights.

Having said this, it is possible to say that Exposure Therapy using Virtual Reality has positive effects in treating Acrophobia, as evidenced in the literature (24).

4. Conclusion

The results of this study seem to contribute to demonstrate that exposure therapy using Virtual Reality has positive results and is a promising therapy in the treatment of individuals with Acrophobia. Although some of the results are not conclusive, it was possible to show that the experimental group obtained promising values regarding reducing anxiety in an anxiogenic context.

Further research is suggested to build more robust evidence in this area, either by conducting more experimental studies with more significant samples and more control of the variables under study.

We propose the continuation of research in this area to obtain more robust scientific evidence.

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