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Design and Evaluation of Virtual Reality Environments for Claustrophobia

Abstract

Claustrophobia is a specific phobia characterized by fear of enclosed spaces (such as elevators, subway tunnels, etc.). While some individuals with claustrophobia might experience only mild anxiety and discomfort in enclosed spaces, others might suffer from panic attacks usually triggered by a fear of losing control or being unable to escape when needed. One of the most recent and successful treatment methods applied in specific phobias are virtual reality (VR)-based exposure therapy techniques. This feasibility study aimed to design and validate a set of immersive virtual environments (VEs) for exposure therapy in claustrophobia, with interactive scenarios enabling systematic, gradual, and controlled induction of claustrophobic fear. In total, eighteen individuals participated in the feasibility study. Participants were recruited from a general population and divided into two groups (phobic vs. control group). Each participant was asked to evaluate a set of various virtual environments. The study results indicate that the designed virtual environments have the potential to induce claustrophobic fear and are thus considered suitable for use in the exposure therapy of claustrophobia. These virtual environments also evoked a sense of presence, particularly the spatial presence component, while the reported cybersickness symptoms were none or minimal.

1 Introduction

Claustrophobia is defined as intense fear and avoidance of enclosed and small spaces with no way to escape. According to the *Diagnostic and Statistical Manual of Mental Disorders* (APA, 2013), claustrophobia is a type of specific phobia, but it can also be considered a type or prodromal stage of agoraphobia (Öst, Alm, Brandberg, & Breitholtz, 2001). To qualify as a phobic disorder, the experienced fear must be excessive or unreasonable and the severity of the anxiety or anticipation, and avoidance, must interfere significantly with the person's life (APA, 2013). About 12.5% of the population suffers from this fear and the majority are women (Vadakkan & Siddiqui, 2022). Feared situations involve, in a claustrophobic person, a strong urge to escape, with the fear of suffocating and the fear of restriction (e.g., restricted hand movements) being referred to as the two main dimensions of this disorder (Rachman, 1997). Typical situations that trigger anxiety are windowless or locked rooms, elevators, underground spaces, tunnels, subway trains, mine tours, and airplanes

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(Wiederhold & Bouchard, 2014). While being exposed to these situations, people with claustrophobic fear experience various emotional and physiological symptoms such as an intense urge to leave, severe anxiety, trembling, difficulty breathing, sweating, etc. (Vadakkan & Siddiqui, 2022). Anxiety and claustrophobia are also common during MRI procedures. It is estimated that about two million scans worldwide cannot be performed annually due to claustrophobic fear, with one out of 100 people experiencing a claustrophobic reaction requiring premature termination of the procedure (Munn, Moola, Lisy, Riitano, & Murphy, 2015).

Exposure-based treatments have been proven effective, especially in the therapy of anxiety disorders, with in vivo exposure (IVE) being the gold standard for phobia treatment. Virtual reality (VR)-based exposure technique offers the possibility of a virtual representation of the feared stimuli and allows exposure in a safe and controlled environment. There is already evidence showing a positive outcome of the VR-based exposure in the treatment of various phobias and other anxiety disorders, including PTSD, panic disorder, etc. Few existing meta-analyses comparing IVE with virtual reality exposure therapy (VRET) are showing that the effectiveness of these approaches is at least comparable. Results can differ depending on the number of sessions, type of treated phobia, or availability of follow-up data. A combination of both approaches (VRET and IVE) appears to be useful, but VRET can also be combined with other methods, for example, with CBT or cognitive training (Freitas et al., 2021; Powers & Emmelkamp, 2008; Wechsler, Kümpers, & Mühlberger, 2019; Wolitzky-Taylor, Horowitz, Powers, & Telch, 2008).

A few virtual environments (VE) for claustrophobia have been developed in previous studies that tested their feasibility and exposure potential (e.g., Botella, Baños, Villa, Perpiñá, & García-Palacios, 2000; Bruce & Regenbrecht, 2009; Rahani, Vard, & Najafi, 2018). The sample sizes ranged from two (Bouchard, Robillard, Larouche, & Loranger, 2012), to four (Botella at al., 2000), six (Malbos, Mestre, Note, & Gellato, 2008), and fourteen (total sample of 33; Rahani et al., 2018) in clinical samples, and from sixteen (Bruce & Regenbrecht, 2009) to eighteen (Christofi & Michael-Grigoriou, 2016) in nonclinical samples. The study by Rahani et al. (2018) is the only one including a control group of volunteers with no fear of enclosed space. Nevertheless, this study does not compare the effect of different environments on explored factors (playability and anxiety level) and at this point aims to decrease users' anxiety after playing the game in which the user can freely choose between two chapters (elevator or MRI room). Virtual elevators, small rooms, corridors, tunnels, or caves are typically used in this type of VR study (for summary on previous studies, see Rahani et al., 2018). Bruce and Regenbrecht (2009) designed an environment of four interconnected rooms with an increasing number of claustrophobic cues, with the first room being spacious and bright and the last room being small, dark, and windowless.

Even though these clinical studies show promising results by means of reduction of discomfort in repeated exposures, the studies report very small samples and to our knowledge, no environments have been constructed specifically for long-term, exposure-based interventions. We argue that more diverse environments combining various provoking stimuli should be designed as a base for future randomized controlled trials. In addition, the existing virtual environments do not offer many opportunities for direct interaction with the present environmental features (such as pressing the elevator's button to use the elevator or when located in the basement, pressing the bell when stuck in the elevator), exposure to social constraints, and fear of losing control. With regard to the prevalence of claustrophobia, estimated as the third most common phobia (Stinson et al., 2007), and the variety of its potential triggers, we decided to implement a set of various cues and scenarios into a single virtual city environment to overcome some of these gaps.

This study aimed to design and test a set of scenarios situated in a single immersive VE to evaluate their feasibility in claustrophobic subjects, by means of measuring the provoked anxiety, induced sense of presence, and potential cybersickness symptoms in comparison to nonphobic individuals. In addition, as a base for a future clinical trial, we aimed to demonstrate the effectiveness of inducing anxiety in the three interactive scenarios in

Table 1. *Sociodemographic Characteristics of the Sample*

	Full sample		Experimental group (reported phobia)	Control group (no reported fear)
Baseline characteristics	N = 18	%	n = 10	n = 8
Gender				
Female	11	61	7	4
Male	7	39	3	4
Highest educational level				
Grammar school	1	5.6	1	0
Middle school	4	22.2	3	1
University or postgraduate degree	13	72.2	6	7
Employment				
Unemployed	1	5.6	1	0
Student	8	44.4	2	6
Employed (part-time)	2	11.1	2	0
Employed (full-time)	7	38.9	5	2

NOTE. N = 18 participants were on average 29.9 years old (SD = 9.2).

terms of anxiety provoked in claustrophobic individuals, when evaluated in standardized levels of difficulty. By comparing this standardized set of graduated situations and evaluating their potential for future use, we would be able to obtain a base for preparing therapy protocols to assess other factors such as the number of treatment sessions.

2 Methods

2.1 Participants

Eighteen volunteers participated in this study: 7 men (ages 20–36) and 11 women (ages 18–50). They were assigned to an experimental group ($n = 10$) or a control group ($n = 8$), depending on their reported fear of enclosed spaces, using the ICD-10 diagnostic criteria as follows: (a) intense fear or anxiety when exposed to small or enclosed space, this fear is (b) irrational, and (c) the person tends to avoid feared situations in daily life (interference with daily life). Participants from the control group did not meet any of these criteria. The sample was recruited from a general population through study advertising on the web page of the National Institute of Mental Health in Klecany, Czechia. The ethics approval was obtained from the internal Ethics Review Committee before the initiation of the study (see sociodemographic characteristics in Table 1).

2.2 Materials

The primary outcome measures were the State-Trait Anxiety Inventory (form STAI-XI), a commonly used measure of trait and state anxiety consisting of 20 self-report items rated on a 4-point Lickert scale, and the Subjective Unit of Distress Scale (SUDS), a self-report scale ranging from 1 to 10 (1 = "no distress," 10 = "extreme distress"). The SUDS scale was used to measure the subjective level of anxiety currently experienced by the participant. This scale is commonly used during exposure sessions.

Before the experiment, participants were asked to rate their level of claustrophobic fear using the Claustrophobia Questionnaire (CLQ). This instrument is a reliable and sensitive measure of claustrophobia and its component fears (of suffocation and restriction) consisting of

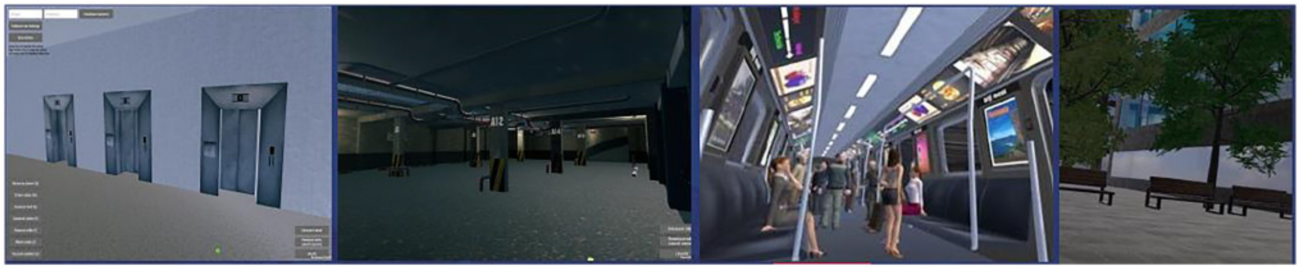

Figure 1. *Illustration of the VRET-city environments applied in claustrophobia as separate scenarios.*

26 items (Radomsky, Rachman, Thordarson, McIsaac, & Teachman, 2001).

After the experiment, sense of presence in VE was assessed using the Igroup Presence Questionnaire (IPQ). This instrument is used to measure the sense of presence in a virtual environment. This questionnaire consists of 14 items and has three subscales: spatial presence (sense of being physically present in the VE), involvement (attention devoted to the VE), and experienced realism (subjective experience of realism in the VE) (Berki, 2019). In addition, the single Overall presence item and the three subscores (IPQ factors) were evaluated as the mean values of the relevant IPQ items (Spatial presence: items 2–6; Involvement: items 7–10; Experienced realism: items 11–14). Finally, the Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993) measured users' level of sickness symptoms caused by virtual reality (VR). It is a subjective cybersickness self-report scale that assesses 16 symptoms of discomfort such as headache or dizziness, divided into three subcategories: nausea, oculomotor symptoms, and disorientation. The revised scoring method suggested by Bouchard et al. (2021) was applied to take into account the effects of anxiety induced by the VR-based exposure on evaluated cybersickness symptoms.

2.2.1 Apparatus. The HTC Vive Pro Head-Mounted Display (HMD) was used to immerse the participant into the virtual experience while providing accurate tracking of the person's head and hand movements. The virtual scene was presented from the first-person perspective and the participant used the HTC Vive controllers for movement and interaction in the virtual environment. The VR-based exposure therapy application (VRET-City) simulates a large virtual city environment developed in collaboration with the Czech Institute of Informatics, Robotics and Cybernetics (CIIRC CTU, Prague) for exposure therapy in different types of phobias (mainly specific phobias, social phobias, and agoraphobia), including several environments that can be combined in a single scenario (e.g., subway, skyscraper, etc.). For the described study, only environments with claustrophobia-inducing cues were used (elevator, subway, and underground parking lot).

2.2.2 Design of Applied Virtual Environments. The game environments were designed based on information provided by the psychiatrist and CBT therapist. The prototype scenarios with increasing difficulty levels were prepared with a small sample of phobic individuals using the principles of human-centered design (Birckhead et al., 2019). The presented study builds on this step and focuses on the feasibility testing and pilot evaluation of the effectiveness of designed VEs in terms of fear-inducing potential. To this end, four different scenarios were evaluated: an elevator, an underground parking lot, a subway, and a neutral environment located under the tree in front of the building (see Figure 1). After that, the VEs were tested and evaluated by volunteers (including a few claustrophobic and agoraphobic patients) to determine their acceptability. Each virtual environment includes different mechanics, allowing design of exposure hierarchies (situations that are graded to induce anxiety). Within scenarios, the therapist can initiate various provoking situations such as blocking the doors, other people blocking the way out, turning off

Table 2. *Description of Individual Steps Performed During the Three Tested Scenarios*

Elevator	Subway	Underground parking lot
Aim: Take the elevator to the 84th floor Number of virtual avatars: 0	Aim: Travel the entire circuit Number of virtual avatars: 10–15	Aim: Get to the 10th floor Number of virtual avatars: 0
Neutral environment (baseline)	Neutral environment	Neutral environment
Elevator doors opening/entrance*	Lower vestibule*	Being in underground level (−1)*
Taking the elevator*	Taking the subway*	Getting stuck, doors blocked*
Getting stuck*	Subway honking*	Getting stuck, elevator blocked*
Getting stuck with lights off*	Getting stuck*	Waiting while being stuck*
Elevator door stuck	Finishing the circuit	Opening of the elevator
Exit	Exit	Exit

NOTE. Selected situations marked with an asterisk (*) were chosen for the statistical analysis (see Figure 2).

the lights in an elevator, being stuck on an underground floor, and a subway train suddenly stopping in the tunnel. The therapist can control some aspects of the VE, but the participant directly interacts with the VE. For example, the therapist can stop the elevator by pressing the dedicated button on the keyboard, while the participant can respond by pressing the virtual emergency button on the elevator control panel. The virtual scenarios are enhanced by visual and sound effects (emergency lighting inside the elevator, elevator squeaking, subway honking), and virtual humans increasing the realism of the simulation. Importantly, individual scenarios were created in the form of a single virtual scene and they could be easily combined as needed during the exposure therapy.

2.3 Procedure

In this feasibility study, volunteers reporting fear of enclosed spaces and volunteers with no reported discomfort were assigned to an experimental or a control group. During a single session, they were exposed to VEs of the three provoking scenarios in randomized order. Before the session, the severity of claustrophobia (CLQ), and the tendency to exhibit avoidance behavior were assessed. General anxiety level was assessed before and after the session (STAI-XI). The sense of presence (IPQ) and cybersickness (SSQ) were assessed at the end of the session. Based on the procedure of Bouchard et al. (2012), VR exposures in individual claustrophobia-inducing environments lasted about 10 minutes, including short breaks (2 minutes) between each immersion, located in the neutral environment (virtual city bench on an empty street, see Figure 1). All scenarios contained a situation of restricted freedom of movement (being trapped in an enclosed environment) of the same duration (120s); for a detailed description of each scenario's steps, see Table 2. The therapist encouraged participants to enter feared situations and to self-report their current distress levels using the Subjective Unit of Distress Scale (SUDS) at specific points (e.g., a few seconds after a stressful moment occurred). Given the nontherapeutic character of sessions, presented situations are rather basic with a moderate level of difficulty.

3 Results

Descriptive statistics of primary and secondary outcomes are described in Tables 3 and 4. The difference in claustrophobic fear between both groups was tested using the nonparametric Mann-Whitney U test (M-W). The group difference in CLQ scores (evaluated prior to group assignment) was statistically significant (M-W $U = 9.5$, $p = 0.008$) with higher scores in the experimental group (see Table 3).

Table 3. *Descriptives of Measured Scales for Experimental and Control Group*

	Experimental group (reported fear)					Control group (no reported fear)				
Baseline characteristics	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD
CLQ score	23	113	55.9	54.5	28.7	13	35	24.5	24.5	7.1
STAI-XI pre	31	52	41.7	43	7.7	27	49	37.1	37.5	7.4
STAI-XI post	26	50	36.8	35	7.6	24	53	33.7	31	10.5
IPQ	−3	27	12.6	12	10.3	−3	21	7.7	10	8.4
Avoidance (yrs.)	1	25	10.1	9.5	8.6	0	0	0	0	0

NOTE. CLQ: Claustrophobia Questionnaire, STAI: State-Trait Anxiety Inventory, and IPQ: Igroup Presence Questionnaire.

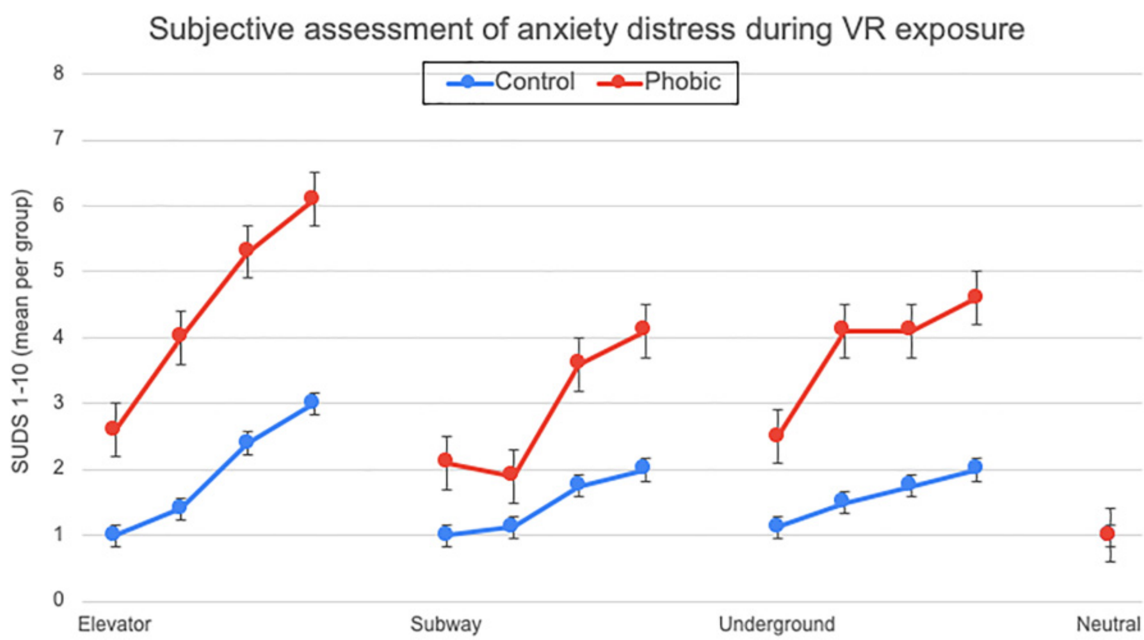

Figure 2. *Subjective assessment of distress during individual steps of the virtual exposure.*

In terms of induced distress ratings, claustrophobic subjects showed higher SUDS ratings (see Figure 2) in all exposure scenarios (except the neutral environment) than nonphobic control subjects (Elevator: M-W $U = 6$; $p < 0.05$; Parking lot: M-W $U = 8.5$, $p < 0.05$; Subway: M-W $U = 9$, $p < 0.05$; Neutral: M-W $U = 32$, $p > 0.05$). The neutral environment did not induce any claustrophobic fear and its rating was equivalent for both groups (mean SUDS = 1). The tested virtual environments could be ordered according to the level of anxiety induced in claustrophobia subjects, with an elevator as the most provoking (mean SUDS of the last evaluated step of the exposure that includes being stuck: experimental group = 6.1, control group = 3.0), followed by the underground parking lot (experimental group = 4.6, control group = 2.0), and the subway rated as the least provoking by both groups (experimental group = 4.1, control group = 2.0).

The STAI-XI scores were compared using a nonparametric Wilcoxon signed-rank test for both groups before

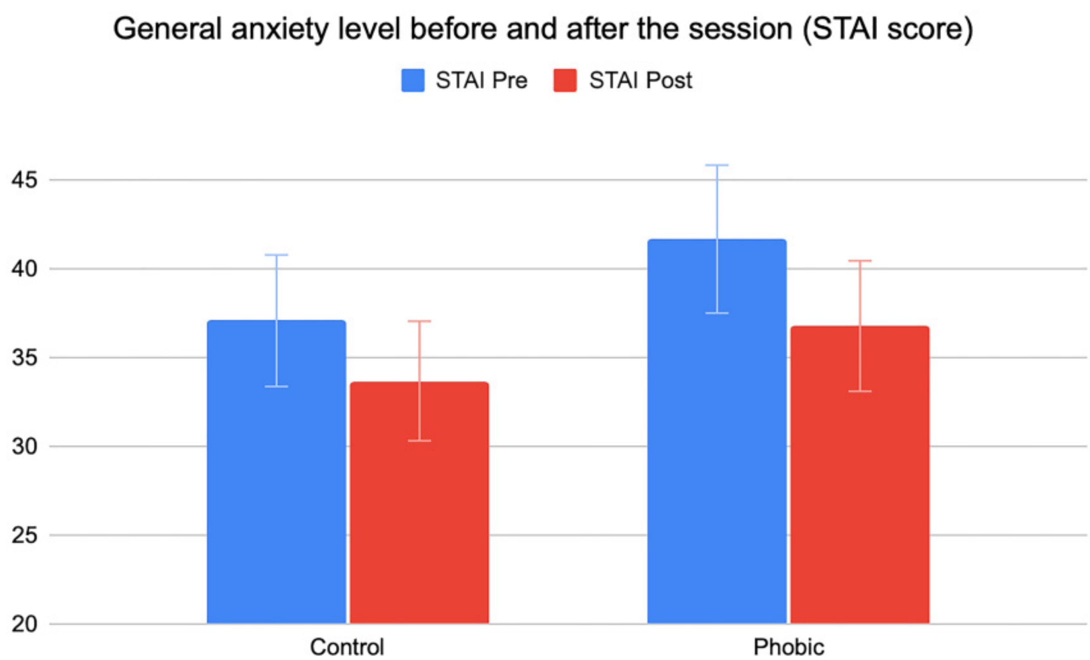

Figure 3. *General anxiety level (STAI-XI score) evaluated before and after the session in both tested groups (mean, SE).*

and after the exposure. The difference in reported anxiety was also tested using M-W U test for group effects before and after the session. No significant change in pre- and post-exposure anxiety was found in any of the tested groups (control group: $W = 20$, $p > 0.05$; experimental group: $W = 37$, $p > 0.05$). Likewise, no significant group difference was found in reported anxiety between the control and experimental group, neither before ($W = 7.5$, $p > 0.05$) nor after ($W = 7.5$, $p > 0.05$) the exposure (see Figure 3).

We were interested in group differences in the IPQ score as the immersive experience of enclosed space could be perceived differently for phobic and nonphobic individuals. The difference between the experimental and the control group in the total IPQ score (see Table 3 and Figure 4) was tested using the nonparametric Mann-Whitney U test that did not show any significant group effect (IPQ: M-W $U = 26$, $p > 0.05$). We also tested the potential group differences in individual aspects (factors) of presence measured by the IPQ subscales (Spatial presence, Involvement, and Experienced realism) and the Overall presence item (see mean scores in Figure 4). Despite the visible difference in the mean score of Overall presence item and the mean score of Spatial presence items, the individual group comparisons did not show any significant effects ($p > 0.05$). In addition, the IPQ total score was correlated using the nonparametric Spearman correlation coefficient with mean SUDS scores (separately for each virtual environment) evaluated in the last exposure situation (see Table 2 and Figure 2). We observed moderate but nonsignificant ($p > 0.05$) correlations between total IPQ score and SUDS scores (for elevator: $r = 0.31$; subway: $r = 0.36$; underground parking lot: $r = 0.37$). Finally, we were also interested in whether the highest rated IPQ subscale of Spatial presence could be associated with the subjective experience of the Phobic subjects in the three virtual environments. The Spearman correlation between the IPQ spatial presence score and the SUDS scores showed positive strong correlation coefficients, but the results were significant only for the Underground environment and a nonsignificant trend for Subway (elevator: $r = 0.51$; $p = 0.137$; subway: $r = 0.63$, $p = 0.053$; underground parking lot: $r = 0.71$, $p = 0.021$). Importantly, the SUDS did not show any significant ($p > 0.05$) association with this IPQ subscore in the control group

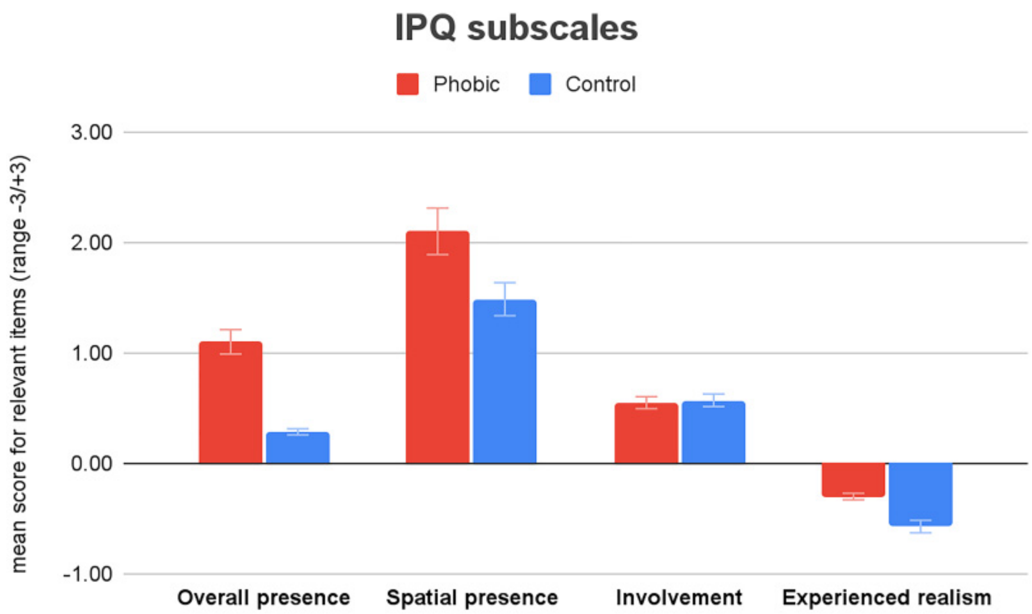

Figure 4. *The IPQ presence questionnaire. The mean scores were calculated for the Overall presence item.*

Table 4. *Descriptive Statistics of the SSQ Including Subscales for Experimental and Control Group*

	Experimental group (Phobic) (reported fear)					Control group (no reported fear)				
Baseline characteristics	Min	Max	Mean	Median	SD	Min	Max	Mean	Median	SD
SSQ score:										
Total Raw score	2	13	5.5	5	3.1	0	7	3.6	4	2.5
Factors										
Nausea	0	8	3	2.5	2.4	0	3	0.9	0.5	1.1
Oculomotor	0	6	2.5	2.5	2	0	7	2.8	2.5	2.3
SSQ-Total-Anx	1	12	4.5	3.5	3.1	0	7	3.3	4	2.2
SSQ-Nausea-Anx	0	7	2	1.5	2.2	0	2	0.6	0	0.9
SSQ-Oculomotor-Anx	0	6	2.5	2.5	2	0	7	2.6	2	2.3

NOTE. SSQ (Simulator Sickness Questionnaire) scoring system suggested by Bouchard et al. (2021).

and the results were inconsistent for individual environments (elevator: $r = -0.5$; subway: $r = 0.43$; underground parking lot: $r = -0.13$).

The tested subjects reported on individual items of the SSQ symptoms in a range from none (0) to slight (2). The group difference in the SSQ (see Table 4) score between the experimental and the control group was also tested using the nonparametric Mann-Whitney U test that did not show significant group effect for the SSQ total raw score (M-W $U = 27$, $p > 0.05$) and the Oculomotor factor (M-W $U = 37.5$, $p > 0.05$), while we observed a significant group effect in the Nausea factor (M-W $U = 16$, $p = 0.03$). When controlled for the potential anxiety impact on this factor (SSQ-Nausea-Anx), the group difference was not significant.

Participants were also asked about their previous experience with VR and their self-perceived level of computer literacy. A majority of them (15 out of 18) already had previous experience with VR, and no one rated their computer literacy as low (33.3% high, 66.7% medium).

4 Discussion

This study aimed to design and consequently validate various immersive virtual environments (VEs) for exposure therapy in claustrophobia. Even though some VEs for claustrophobia have been created and small sample or case studies showed marked improvements, except for one study (Rahani et al., 2018), the combinations of experimental and control groups are still missing. We address the complexity of claustrophobic fears by evaluating different scenarios with a range of potentially triggering situations (Wiederhold & Bouchard, 2014), every one including a moment of failure. The scenarios also include virtual humans and realistic visual and sound effects. In this pilot study, we compared two groups of subjects (phobic and nonphobic) in subjective outcome measures.

All tested VEs (elevator, subway, underground parking lot) demonstrated a gradually increasing distress induced by the standardized levels of difficulty created and tested for each scenario. When comparing the three virtual environments, the most anxiety-provoking situation was being stuck in an elevator, probably related to avoidance of elevator rides, which can be quite easily achieved in real life and is common in people with claustrophobia. The least provoking environment seems to be the subway, which is, based on our case studies, more anxiety-inducing for agoraphobic patients. It cannot be ruled out that the lower distress ratings in the subway environment could be related to the presence of virtual humans used to simulate an ecologically valid situation, as their presence could give the impression of security to a certain extent. However, individual verbal reports of the participants do not indicate that and suggest the necessity to use this public transportation when living in a big city as a reason. The underground parking lot induces intermediate anxiety. Interestingly, participants from the experimental group commented on ventilators in the underground parking lot with fear of suffocation due to lack of air, compared to the control group, which didn't pay attention to this environmental feature. The ventilators were not originally intended as anxiety-inducing stimuli. Nevertheless, they represent a potentially relevant stimulus we can emphasize more in future clinical studies, making the underground environment even more challenging.

The general anxiety levels (STAI-XI) reported before and after the exposure did not differ significantly between the groups. Importantly, contrary to our expectations, we did not observe the increase in anxiety level after the exposure to claustrophobic scenarios. In contrast, the measured anxiety showed slight but nonsignificant decrease after the exposure in both tested groups (in line with another study using VR-based exposure in claustrophobia; Rahani et al., 2018). This could be related to anticipation anxiety, often reported in people with phobia (Straube, Mentzel, & Miltner, 2007).

We did not find any significant group difference regarding reported sense of presence in tested virtual environments; however, the items of the Spatial presence subscale and the single Overall presence item show some difference (higher values) in phobic participants. The Spatial presence refers to the sense of being physically present in the VE, which could be specific when claustrophobia is induced in VEs, even though they might not be perceived as realistic. This is in line with the strong correlation identified between the IPQ Spatial presence (mean score) and induced distress (SUDS) reported by the phobic subjects in some of the virtual environments. This association is most pronounced in the least provoking environment of the Underground parking lot and in contrast the weakest association was found for the most provoking Elevator environment, probably due to low variability of the responses of phobic participants in this smallest environment.

In terms of negative side effects of the immersive experience, both groups reported minimal or no cybersickness symptoms. The total SSQ score did not differ between the groups, but nausea-related symptoms were evaluated as stronger in the phobic subjects. However, we argue that these symptoms should not be attributed to the VEs, as they might be associated with the anxiety induced in the virtual environments. This is supported by the results obtained using the alternative scoring system suggested by Bouchard et al. (2021), which caused a considerable drop in the previously identified group difference.

Despite the limited sample size, the presented findings indicate the feasibility of the presented virtual environments and their ability to induce claustrophobic fear. These results will create a base for a larger clinical study exploring the therapeutic potential of our VRET-City application.

4.1 Limitations

The small sample size represents the main study limitation that could affect the study results. However, the obtained results that are consistent with the hypothesized effects support the study's findings. Another limitation of the study is the presence of virtual humans in one of the evaluated scenarios, in contrast to their absence in the other two scenarios. This decision was based on simulation of realistic scenes, but it could potentially affect the distress ratings obtained from the claustrophobic participants (e.g., it might lower the distress from being restricted when in presence of virtual humans). Moreover, we did not perform a structured diagnostic interview (only basic ICD-10 criteria have been verified) that would allow us to rule out a potential overlap with agoraphobia that could be affecting obtained results.

4.2 Future Work

These limitations will be addressed in the future clinical study including a larger sample. A differential diagnosis of claustrophobia, agoraphobia, or other similar phobias (e.g., cleithrophobia) will be performed. Future assessment of the environments should also consider presence or exclusion of virtual human(s) in individual scenarios, as this factor might potentially affect the level of anxiety perceived in claustrophobic or agoraphobic patients. Our environment connecting various virtual scenes with or without virtual characters might be suitable in future clinical work. Even though agoraphobia and claustrophobia are two distinct conditions, some authors consider claustrophobia a prodromal stage of agoraphobia (Öst, Alm, Brandberg, & Breitholtz, 2001). Specifically, it would be easy to add more virtual characters in the virtual scenes to evoke more crowdedness, which is typically associated with agoraphobia. Finally, the VR-based exposure should be combined with the measurement of physiological signals (such as ECG and skin conductance) that was partially implemented and tested in this study with a small subset of participants (data are not reported).

5 Conclusions

The feasibility study evaluated a set of immersive VEs of an elevator, a subway, and an underground space in claustrophobic and nonphobic individuals. The study results indicate that the designed VEs have the potential to provoke claustrophobic fear in phobic individuals and might be suitable for virtual exposure therapy in claustrophobia. We aimed to create an immersive experience and our findings suggest that this set of environments induced an overall sense of presence and particularly spatial presence, which was associated with the distress induced in phobic subjects in individual environments. Moreover, the perceived cybersickness symptoms were only minimal and could be mostly attributed to anxiety symptoms provoked by the VEs. Finally, individual VEs showed various levels of induced stress, but each environment tested in several standardized levels of difficulty demonstrated a gradually increasing distress induced by the VEs. This is extremely important, as it creates a base for the design of therapeutic protocols that could be utilized in a future clinical trial addressing the effectiveness of exposure therapy in the targeted clinical population. Future studies must pay attention to the factor of virtual characters, as their presence could modify the provoking potential of individual environments. However, the use of the social element opens up new possibilities for a potential therapeutic use in agoraphobia.

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