Virtual environments design assessment for the treatment of claustrophobia

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***Abstract*—Virtual reality exposure therapy (VRET), can help the lives of many people. Its advantages over other treatment methods for psychological disorders and more specifically phobias, like its cost effectiveness and control, make it the method that we should focus on. Claustrophobia is the phobia that we have studied. Creating suitable claustrophobic virtual environments (VEs) for patients to get immersed in, is crucial if we want to eventually treat them only with the use of VRET. We designed and developed a virtual reality (VR) framework that allows us to investigate whether VR can reproduce anxiety due to claustrophobic aspects and investigate which characteristics of the virtual environments design contribute to this. Three characteristics (space openness, tidiness and color) have been investigated through this study with our results indicating that they may affect the feeling of anxiety.**

I. Introduction

Virtual reality is widely used in many different fields like in education [1], in training [2], in video games [3], in heritage [4] and in psychology [5]. The effective use of virtual reality applications for the treatment of psychological disorders like phobias and specifically claustrophobia, has been proven by a lot of studies through the years [6].

Virtual reality exposure therapy (VRET) can help people change the way they think, act and interpret information [7]. It brings them face-to-face with their fears in a safe environment, where knowing that the situation is harmless, they can deal with them safely [8]. It has many advantages over vivo exposure; it's more convenient and cost effective [9]. For the fear of flight for example, it's impossible to make a patient fly over and over again with a real airplane until his/her fear reduces, whilst with VRET, you can repeat the process, as many times as it is needed. Another advantage is that the developed VR application can be completely controlled by the therapist and by the patient [6].

It is important though, if we want this method of treatment to be as reliable and successful as possible, to fully understand the human behavior in claustrophobic environments. We need to identify what characteristics make the environments claustrophobic and what makes people anxious there.

A virtual reality application was designed and developed and an experiment took place in order to study this. The reasons and ways the environment made the participants anxious were examined from their own reports combined with the observation of their behavior during the experiment. Moreover, with the use of questionnaires, their level of anxiety and claustrophobia were measured, and the relationship between the amount of claustrophobia a person has and specific behaviors in the VEs was checked. Lastly, it was investigated whether the gender of the person affects their anxiety. This way, we will be able to create the ideal claustrophobic environments in future VR applications for patients to be immersed in and to effectively treat their fear.

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II. Related Work

Numerous studies have been conducted through the years proving the efficacy of virtual reality applications for the treatment of a lot of phobias. Arachnophobia is one example of a phobia that was successfully treated with the use of VRET [7]. The patient was a woman suffering from it for 20 years. The researchers created a VR application specifically for arachnophobia. After the sessions, her fear was greatly reduced and she was able to hold a tarantula for several minutes with little anxiety. Acrophobia was also successfully treated with VRET [10]. In this case report, their subject was a 19-year-old student whose fear of heights was reduced after their sessions. VRET was also efficient for the treatment of the fear of public speaking in university students [11]. Amongst other phobias, VRET can treat and more serious psychological problems like post-traumatic stress disorder (PTSD) [12].

The phobia that has been studied in our work is claustrophobia. It is a situational phobia that has to do with extreme anxiety in enclosed spaces and physically restricting situations [13]. It has been proven that claustrophobia is composed of two elements: the fear of suffocation and the fear of restriction [14]. It can be treated with cognitive behavioral therapy (CBT), with relaxation exercises, with a drug therapy, natural medicine or with the use of virtual reality. A study concerning claustrophobia has shown that we can achieve greater effects when the method of treatment fits the patients response pattern than when it does not [15].

The case study [6], involved a 43 year old woman, whose extreme fear and anxiety, could not let her undergo a CT scan. In order to treat her fear, they created two settings. The first setting had three environments with increasing degrees

of difficulty. The first environment was a balcony or a small garden 2 × 5 m, the second was a room 4 × 5 m which communicated with the balcony and had doors and a large window which could be opened and closed and the third was a room 3 × 3 m which communicated with the other room. This room had no furniture or windows. There was also a wall which could be moved by the patient and it was making noise, leaving the patient eventually in a small 1 × 1 m space. In the second setting there was a wide entrance with a large window. From this entrance, the patient had access to an elevator which was designed in such a way so it could offer many different scenarios to the patient, taking account different variables like the size of the elevator, its location and the possibility of the elevator blocking. After eight 45 minutes long VR sessions, her fear and avoidance measures dramatically decreased.

A recent study [16] proved the effectiveness of a multiple component therapy for claustrophobia which also included the use of virtual reality. Six participants who suffered from claustrophobia volunteered to take part in the experiment. Three of the participants also suffered from acrophobia, agoraphobia and the fear of driving. They had eight sessions in total. The first three sessions consisted of various components: psychoeducational, relaxation initiation, cognitive restructuring and homework assignments. The rest of the sessions included VRET with the use of 9 different VEs. Their results from questionnaires and behavior tests showed a significant reduction in fear of closed spaces and quality of life improvement.

An even more recent study [17], investigated the efficacy of an immersive VRET prototype system for the treatment of claustrophobia. Their application was affordable, robust and practical and it provided presence and effectiveness in treatment. They evaluated it heuristically using a non-clinical sample like in our study. The environments in this study were four interconnected rooms with an increasing number of claustrophobic cues. The first room was a bright and big living room and the forth room was a small dark room with no windows.

The role of presence, which can be defined as the "feeling of being in a world that exists outside of the self" [18] or as the "sense of being there" [19] in VRET has been also studied [20] and showed a direct connection between the intensity of the emotions experienced in VR and the level of presence elicited by it.

In another study by Price [21], the results supported that presence is a factor that contributes to the experience of anxiety in VEs and that there is a relation between presence and the phobic elements, but did not support a relation between presence and treatment outcome. It suggested that presence may be a necessary but insufficient requirement for successful VRET.

In another study, Wrzesien et al. [22] proposed a theoretical model of the VR/AR-Mediated Therapeutic Process. The final part of the model refers to the presence and the reality judgment constructs, which both play an important role in the effectiveness of the VRET and ARET. They note that the technology characteristics such as the quality of graphics, the display, or interaction metaphors can influence the sense of being in the anxious situation (presence) or the sense of feeling this situation as real (reality judgment) and that they have an effect on the reactions of the clients (increase in anxiety or decrease in anxiety after a certain time of exposure), and on the final effectiveness of the therapeutic process.

However, none of these studies actually checks the appropriateness of the VEs used in the VRET applications developed and this is what our study investigates.

III. Method

We designed a VR application specifically for claustrophobia with a within-group experimental design. All the participants, experienced all the VEs that were developed.

A. Subjects

Eighteen students (8 male and 10 female) from our University's campus, with a median age of 23 years (range 20 - 25) participated in the experiment (Fig. 1). Ten of them had a virtual reality experience 1-3 times before, five of them had 1-4 times, two of them have in a weekly basis and one of them had never had a VR experience. Before participating, they were asked to read and sign the consent form of the experiment. It is important to note that the participants had no prior knowledge concerning the subject of the experiment and they were not informed about it neither during the experiment. Then they all had to fill in a demographics questionnaire before the start of the experiment.

Fig. 1. A participant (on the right) wearing the HMD, holding the controller and being immersed in the virtual environment.

The subjects were not clinically diagnosed with claustrophobia. They were viewing the VEs from a first person perspective. Five of them were not able to finish the experiment due to reported nausea caused by the Oculus Rift.

B. Apparatus and VEs

The VR system included the Head-Mounted Display Oculus Rift DK2 coupled with a positional tracker. The desktop computer used for the experiment was equipped with an NVidia GeForce GTX 770 graphics card. A SPEEDLINK TORID wireless gamepad and SPEEDLINK Stereo Speakers were also used.

The VEs were created with the game engine Unity3D (http://unity3d.com/unity) and consisted of five different VEs in total. The 3D models that were used in the VEs were created with the software Autodesk Maya (http://www.autodesk.com/products/maya/overview).

The first environment (VE-1) was a wide open outdoors space, with buildings, two houses, an empty road with two cars parked at its two ends, grass, trees and mountains around (Fig. 2). This environment was also used as a tutorial level for the participants, in order for them to get familiar with the controller and the Oculus Rift.

Fig. 2. The outdoor space used as a tutorial environment for the familiarization of the user with the controller and HMD

The second environment (VE-2) was the inside of a house. The house had four rooms, the kitchen, a kids room, the parents bedroom and the bathroom (Fig. 3). These rooms were all different in size and three of them were messy, having different objects thrown all over the room. The participants had to go into all four of them in a specific order. The biggest room in the house (8 $\times$ 7 m) was the kitchen (Room-1). It had a white ceiling, a white/gray wallpaper on the walls, wooden cabinets, a stand and three kitchen stools, broken plates and glasses thrown on the floor. The kids room (Room-2) was a smaller room than the kitchen (6.5 $\times$ 6 m). It has a pink wallpaper on the walls, a lamp, a chair and toys thrown to the floor. The parents bedroom (Room-3) was a slightly bigger room than the kids room (7.5 $\times$ 6 m). It has a brown wallpaper on the walls and brown colored furniture. This is the only room in the house that is tidy. The bathroom (Room-4) was the smallest room in the house (5.5 $\times$ 6 m). It has a light blue wallpaper on the walls, white colored cabinets and toilet papers thrown on the floor.

The third environment (VE-3) was another open outdoors space with an empty road, grass, mountains around and a gray stoned, short in height (4 m), not so wide in width (6 m) and long in length (139 m) tunnel which the participant had to walk in and traverse (Fig. 4).

The fourth environment (VE-4) was a cellar. In the cellar there are barrels and cabinets with bottles of wine which make a defined, restricted and narrow path for the participants to follow (Fig. 5).

The fifth and final environment (VE-5) was another wide open outdoors space, similar to VE-1, with the difference that the focus of this environment was a modern, tall gray building. This building had two entrances, the first one being revolving doors at the front and an open door at the back of the building (Fig. 6). The participants had to choose one of these entrances in order to get into the building.

The VEs were all illuminated in the same way, using ambient and directional lighting to simulate sunlight in outdoor spaces.

C. Measures

The level of anxiety of the participants in the VEs had to measured. When they completed the requested task in each environment, they were asked to grade orally their experience using a five-point Likert scale: 1 = very pleasant, 2 = pleasant, 3 = neutral, 4 = moderately anxious and 5 = extremely anxious (Table III).

TABLE I
THE QUESTIONNAIRE ABOUT THE SUBJECTS ANXIETY IN EACH VIRTUAL ENVIRONMENT

Q1: In the tutorial scene, how would you describe your experience?
Q2: In the kitchen, how would you describe your experience?
Q3: In the kids room, how would you describe your experience?
Q4: In the parents bedroom, how would you describe your experience?
Q5: In the bathroom, how would you describe your experience?
Q6: In the tunnel, how would you describe your experience?
Q7: In the cellar, how would you describe your experience?
Q8: In the scene with the building with two entrances, how would you describe your experience?

Presence Questionnaire (PQ). Five questions from the PQ [23] were chosen for the participants to answer (Table II). These questions were about how real the VEs felt to them and whether the controller and the Oculus Rift interfered or distracted them from performing their assigned task. They were measured with a five-point Likert scale with 1 representing the lowest value of "Not at all" and the value of 5 representing the highest value of "Completely".

Claustrophobia Questionnaire (CLQ). The CLQ [24] is a 26 item questionnaire, where the two components of claustrophobia are measured: suffocation, which is the condition of being deprived of oxygen and restriction which is the act of keeping something or someone within specified bounds. It was used to measure the claustrophobia of the participants. This questionnaire was handed to the subjects at the end of the experiment, and not before so that they could not suspect the subject of the experiment.

Additional measures were taken in the cellar and tunnel scene. The application was programmed to automatically record the distance that the subjects traversed in these two VEs, and the time that took them to complete their task. Their speed was also later calculated.

TABLE II
THE FIVE PRESENCE QUESTIONS OF THE QUESTIONNAIRE

Q1: How realistic did you feel that the environments were?
Q2: How much did the Oculus Rift distract you from performing the assigned tasks?
Q3: How much did the controller distract you from performing the assigned tasks?
Q4: How much did the Oculus Rift affect you performing the assigned tasks?
Q5: How much did the controller affect you performing the assigned tasks?

Fig. 3. The four rooms of the house. Top left is the kitchen, top right is the kids room, bottom left is the parents room and bottom right is the bathroom

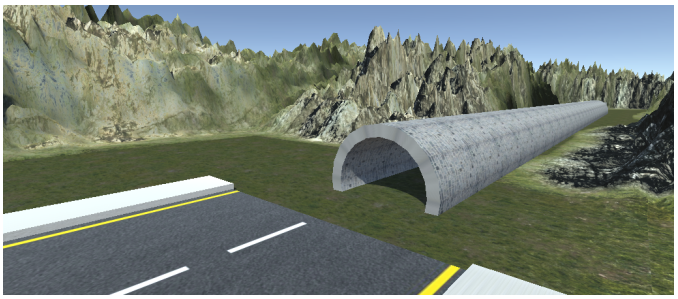

Fig. 4. The environment with the tunnel

Fig. 5. The cellar

D. Procedure

The subjects were entering one at a time the room where the experiment took place. At first they had to read and sign the consent form of the experiment. Then they had to fill a demographics questionnaire which included information about their gender, age, education, work and previous VR experience.

It was then emphasized to them that if they felt uncomfortable at any time in the VE that they were experiencing, or they wished to terminate the experiment for any reason, they had to press the "emergency button", which was a button on the controller, or report it to the instructor and take off the HMD without any need for any explanation. Afterwards they were fitted with the HMD and were given the controller and the experiment could begin.

Firstly, their familiarity with the controller and the Oculus Rift took place with the use of the VE-1, the tutorial level, which is an outdoor space were the participants could test all the functionalities like navigating and running in the environment. The turn in which the participants experienced the rest of the scenes was random. When each scene was loaded, the instructions were given to the participants orally.

More specifically, in each scene they were instructed to locate and retrieve a key or a number of keys. When that happened, the music changed, indicating that they had completed their task. The reason why the participants were given a task, is that this way, they were "forced" to navigate in the scenes. Additionally, the location of the keys directed the participants. In the tutorial scene it was told to them where to locate the key. In VE-3 and VE-4, the key was placed at the end of the tunnel and cellar respectively, whilst the starting position of the participant was at the entrance of them. In VE-2, a key was placed in each room, so that the participant was "forced" to go into all of them in order to retrieve the keys. Finally in VE-5, the key was placed inside the building, in order to make the participant choose one of the entrances to enter the building.

When the participant finished his task, he was asked to grade orally his experience in that environment using a five-point Likert scale and then he was asked to justify his response.

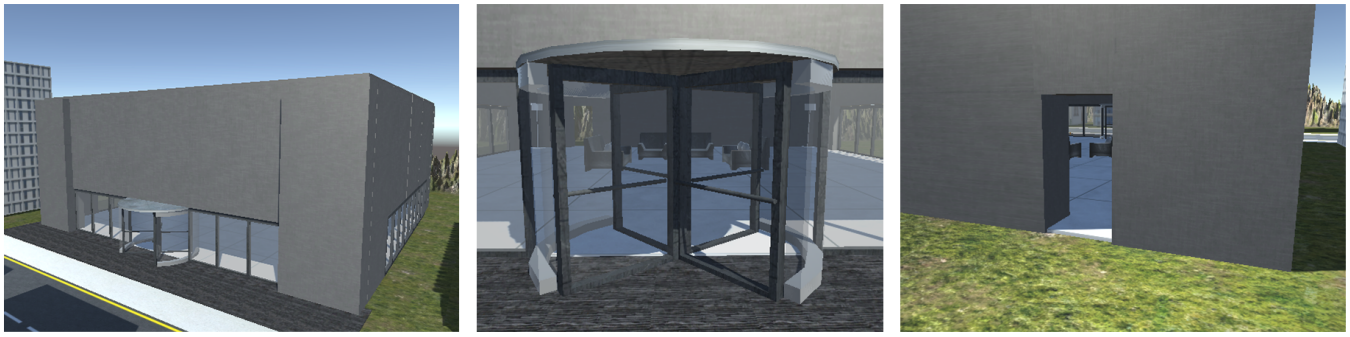

Fig. 6. On the left is the building with the two entrances, on the middle the revolving doors and on the right is the back door

The responses were written down by the instructor who was also observing and writing down the participants' behavior in the VEs. Afterwards, the next scene was loaded.

When the participant finished with all five scenes, the HMD was removed from them as well as the controller and they were given to fill in the Presence and Claustrophobia Questionnaires. All the questionnaires were in the native language of the participants. The experiment lasted approximately 20 minutes.

IV. Results

The statistical analysis was done using the IBM SPSS software (www.ibm.com/software/analytics/spss/).

Firstly, comparing the means of the amount of anxiety that the subjects reported after experiencing each of the VEs, the most claustrophobic VE was found to be VE-4, the scene with the cellar (N=15, M=3.07, SD=1.10) and the least was VE-5 (N=14, M=1.93, SD=.730) (Table III).

TABLE III
Mean and standard deviation of the subjects anxiety in each virtual environment

	Room-1	Room-2	Room-3	Room-4	VE-3	VE-4	VE-5
N	16	16	16	13	14	15	14
Mean	2.56	2.56	2.13	2.46	2.57	3.07	1.93
SD	1.315	1.153	1.088	1.266	1.399	1.100	.730

To identify the characteristics that contribute to claustrophobic aspects within an environment, the developed VEs were classified in the analysis using three different parameters. The first characteristic was the 'color' in which the VEs were separated into two groups concerning the dominant color inside the VE. These two groups were the 'pale' colored VEs (Room-3, VE-3, VE-4, VE-5) and the 'vivid' colored VEs (Room-1, Room-2, Room-4, VE-1). The second characteristic was whether the VE is an 'open' space or a 'closed' one. These two groups were the open spaced VEs (VE-1 and VE-5) and the closed spaced VEs (VE-2 (all the rooms), VE-3 and VE-4). The third and last characteristic was used for the rooms in the house and it was referring to whether the room is messy or not. These two groups were the 'messy' rooms (Room-1, Room-2, Room-4) and the 'tidy' room (Room-3). The mean reported anxiety of each participant in each group was computed and used for the analysis (variables gpale and gvivid concerning characteristic 1, gopen and gclosed for characteristic 2, gmessy and gtidy for characteristic 3) (Table IV).

TABLE IV
The separation of the virtual environments using the three factors

	VE-1	Room-1	Room-2	Room-3	Room-4	VE-3	VE-4	VE-5
open	X							X
closed		X	X	X	X	X	X	
tidy				X				
messy		X	X		X			
vivid	X	X	X		X			
pale				X		X	X	X

The mean score of the messy rooms - gmessy (N = 13, M=2.589, SD=1.08) was bigger than the tidy room - gtidy (N = 13, M=2.00, SD=1.00). Also the mean score of the pale colored VEs - gpale (N = 13, M=2.403, SD=.794) was bigger than the vivid colored VEs - gvivid (N = 13, M=2.365, SD=.938). Finally the mean score of the closed spaced VEs - gclosed (N = 13, M=2.576, SD=.818) was much more bigger than the open spaced VEs - gopen (N = 13, M=1.807, SD=.192).

A paired-samples t-test was conducted to compare these means of every characteristic. There was a significant difference only between gopen (M=1.80, SD=.693) and gclosed (M=2.57, SD=.818); t(12)=-6.178, p = 0.000.

In order to identify what makes people anxious in the VEs we had to look at their own reports, their justifications for the grades they were reporting after experiencing each VE. In Room-1 of the house, the kitchen, one male participant reported that the mess made him upset and anxious, and that he was afraid that something happened in the kitchen, or might happen to him, which agrees with the proposal that the claustrophobic person is not afraid of the enclosed space as such, but what might happen to him there [25]. In all the messy rooms in the house, the subjects commented about the mess in their answer. For VE-4, the cellar, a female participant commented about the low ceiling, and that the barrels and cabinets were too close to her and that made her anxious.

The observation of the participants and their comments while experiencing the VEs was another way to study their behavior in the VEs. An interesting behavior that was noticed was that the participants tended to move quicker in the VEs,

pressing the appropriate button on the controller, when they were more anxious and even reported that they were closing their eyes while doing that.

The claustrophobia level (clq score) of each subject was also measured. A Pearson product-moment correlation coefficient was computed to assess the relationship between the amount of claustrophobia of the participants and their anxiety in the VEs (Table V). There only significant (1-tailed) correlation was a weak positive between clq score and their anxiety in VE-3, r = 0.498, n = 14, p = 0.035.

TABLE V
PEARSON PRODUCT-MOMENT CORRELATION BETWEEN THE CLQ SCORE OF THE PARTICIPANTS AND THEIR ANXIETY IN EACH VE

	Room-1	Room-2	Room-3	Room-4	VE-3	VE-4	VE-5
N	16	16	16	13	14	15	14
r	.358	.227	-0.77	.259	.498*	.314	.313
p	.087	.199	.388	.197	.035	.127	.138

*p $<$ 0.05

An independent-samples t-test was conducted to compare the mean anxiety of men and women participants in the VEs. There was a significant difference only in Room-3, men (M=1.43, SD=.535) and women (M=2.67, SD=1.118); t (14)=-2.686, p = 0.018.

The sense of presence, as measured in Q1 of the PQ was found moderate, with a median score of 3 out of 5. The amount of distraction of the Oculus Rift (Q2) and the controller (Q3) was quite low, with medians of 2 and 1 respectively. Also low scores were measured in the last two questions, Q4 and Q5, referring to how much the Oculus Rift and controller affect the participants, with both medians at 2 out of 5.

A Pearson product-moment correlation coefficient was computed to assess the relationship between the level of immersion of the participants, as declared by them at Q1 of the PQ and their anxiety in each of the VEs. Only in VE-3 the correlation was found positive (r = .124, n = 14, p = 0.672), while the rest of the correlations were found negative, which contradicts the findings [21] that presence is a characteristic that contributes to the experience of anxiety in VEs. None of this correlations was found significant.

V. CONCLUSION

This experiment has been conducted to identify characteristics for the design of virtual environments that contribute to claustrophobic aspects. Our results agree with those of Malbos et al. [16] and Bruce and Regenbrecht [17] which demonstrated that VR environments can be used for conducting VR studies related to claustrophobia. The main characteristic of a physical space that contribute to the claustrophobic fear, the closeness of a space, based on our results it is associated with a significant correlation with anxiety of participants also within VR environments. This implies that VR is a suitable tool to investigate aspects related to claustrophobic fear.

Moreover we presented a complete framework with which association of other characteristics of environments related to claustrophobia can be studied. Our proposed framework constitutes of several virtual environments which they differ in a number of characteristics that we are investigating. More specifically using our framework, besides the openness of the space, we studied the colors appearing within the environments and the rooms' tidiness. However the virtual environments can be easily extended to integrate other parameters under investigation, such as sound, various illumination conditions, existence of other avatars within the scene etc.

Our results, based on participants'reports, indicate that the mess in the rooms of the house is a characteristic that made people anxious. An increase amount of anxiety in the messy rooms of the house comparing to the tidy one has been also measured, however with a no significant difference. Similar, were the findings for the colors used within the VEs, for which our results indicate that the pale colored VEs made the participants a bit more anxious that the vivid colored ones, contradicting previous findings [26] where results demonstrated that people find pale colors relaxing, calming, and pleasant in contrast to vivid colors that people associated with depression and stress. Further investigation for these characteristics is needed. Moreover, it has been significantly demonstrated that the gender of the participant is not affecting their anxiety within the VEs.

In future studies, we would like investigate further characteristics that may contribute to the anxiety feeling and extend our framework towards helping people to overcome this fear.

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