Using Augmented and Virtual Reality for the development of acrophobic scenarios. Comparison of the levels of presence and anxiety

Juan, M.Carmen[1*], Pérez, David[2]
[1] Instituto Universitario de Automática e Informática Industrial, Universidad Politécnica de Valencia, Camino de Vera, s/n. 46022 Valencia, Spain
[2] LabHuman, Universidad Politécnica de Valencia, Camino de Vera, s/n. 46022 Valencia, Spain

Abstract

Acrophobia has been treated using exposure in imagination, exposure "in vivo", and Virtual Reality (VR). This paper presents the development of an Augmented Reality (AR) system and a VR system that includes acrophobic scenarios. A study involving both these systems and non-phobic users has been carried out in order to compare the levels of presence and anxiety. In the acrophobic scenario, the floor fell away and the walls rose up. Twenty participants took part in this study. After using each system (AR or VR), the participants were asked to fill out an adapted SUS questionnaire (Slater et al., 1994), and paired t-tests and ANOVA analyses were applied to the data obtained. For the sense of presence and anxiety levels, we did not find differences between the systems using an experiment with enough sensitivity to detect differences as large as d = .66. For the anxiety level, the results show that there is a significant difference between the level of anxiety felt at the moment before starting the experiment and the level felt during the different stages of the experiment. For the correlation between anxiety and presence, the results show very low correlation between anxiety and presence. These results suggest that AR is likely to be as effective as VR in treating acrophobia.

1. Introduction

Acrophobia is an intense fear of heights and consequent avoidance of locations that are related to heights (e.g., balconies, terraces, elevators, skyscrapers, bridges, planes, etc.). People who suffer from acrophobia know this fear is excessive or unreasonable, but they still fear any situation that involves heights, even when it is other people who are in those same situations. The greatest fear is falling. The most common treatment for acrophobia is "graded in vivo exposure". In this treatment, the avoidance behavior is broken by exposing the patient to a hierarchy of stimuli. Stimuli may include, e.g., climbing on the stairs of a 12-story building. After a time, habituation occurs and the fear gradually diminishes. Several studies have focused on the effectiveness of treating acrophobia with Virtual Reality (VR) (e.g. Rothbaum et al. [1]), some of which make comparisons with exposure in vivo (e.g. Emmelkamp et al. [2]).

VR is an attractive technology for therapy since the situation can be designed according to the key elements of a specific problem, generating the same reactions and emotions in the patient that he or she would experience in a similar situation in the real world. Different environments can be generated (objects, places or situations) in which the patient experiences sensations similar to those he or she would have in a real environment, however, since the environments are computer-generated (and therefore virtual), there is no need for the patient to move to a real place. Virtual Reality Exposure Therapy (VRET) uses VR as a tool for therapy. Several case studies show that acrophobia can be treated effectively with VRET [1, 3]. In addition, VRET is based on the assumption that virtual environments can elicit anxiety and provide the opportunity for habituation [4]. In the DSM(Diagnostic and Statistical Manual of Mental Disorders)-IV [5], anxiety is defined as an "apprehensive anticipation of future danger or misfortune accompanied by a feeling of dysphoria or somatic symptoms of tension". This definition implies that anxiety is a future-oriented state, that causes the organism to behave so that the danger can be averted.

The sense of presence has been defined as the psychological perception of "being in" or "existing in" the Virtual Environment in which one is immersed [6, 7]. Several studies support the idea that emotions such as fear or anxiety, which are felt during immersion, are related to presence [8-13].

Recently, Augmented Reality (AR) has also been presented as an available technology for treating phobias [14-16]. However, to our knowledge, the sense of presence and anxiety have not been compared in AR and VR systems that include acrophobic scenarios. The equivalence of AR and VR for presence and anxiety measures could be potentially important for a major application area of virtual environment technology. In this paper, we present the development of an AR system and a VR system that includes acrophobic scenarios, and a study involving both these systems in which the levels of presence and anxiety have been compared. The primary hypothesis of this study is that an AR system and a similar VR system that include acrophobic scenarios will not have significant differences between them with respect to the induced sense of presence and anxiety with non-phobic participants and that a correlation will be found between anxiety and presence in these two systems. The main objective of this work was to examine the sense of presence, the anxiety level, and the relationship between them using the AR and the VR systems.

This paper is organized as follows. Section 2 focuses on background about the relationship between fear/anxiety and presence, VRET, the treatment of acrophobia using VRET, and AR. Section 3 describes the software and hardware requirements as well as the technical features of the AR and the VR systems. Section 4 presents the results of the study for: the sense of presence, the level of anxiety and correlation between them. Finally, in section 5, we present our conclusions, and future work.

2. Background

With regard to the relationship between fear/anxiety and presence, in a study that involved participants without phobias, Regenbrecht et al. [8] used regressions to control the impact of other subjective variables on the sense of presence. They also deduced that the level of fear during immersion increases proportionally with the sense of presence. In another study with participants suffering from acrophobia, Schuemie et al. [9] reported a significant correlation between the level of fear and the sense of presence during immersion. In another study with participants suffering from arachnophobia, Renaud et al. [10] found a significant relationship between the level of anxiety during immersion and the sense of presence, and motor behavior in a virtual task. Robillard et al. [11] carried out a study that included participants with and without specific phobias exposed to a virtual environment. They found a significant correlation between the level of state anxiety and the level of presence experienced during immersions in the virtual environment. In a study with 31 participants suffering from snake phobia, Bouchard et al. [12] presented a randomized within-between design with two conditions and three counterbalanced immersions: (a) a baseline control immersion, (b) an immersion in a threatening and anxiety-inducing environment, and (c) an immersion in a non-threatening environment that should not induce anxiety. The measures of presence were significantly higher in b) than in either a) or c). Their finding was not corroborated by the presence questionnaire, where scores varied significantly in the opposite direction. However, the results from the brief one-item measure of presence did support the significant contribution of emotions during the immersion to the subjective measure of sense of presence. They also found correlations between anxiety and presence. In [13], Juan and Perez compared the levels of presence and anxiety in an acrophobic environment that was viewed using a Computer Automatic Virtual Environment (CAVE(tm)) and a Head-Mounted Display (HMD). In this environment, the floor fell away and the walls rose up. Twenty-five participants took part in this study. A significant correlation between anxiety and presence was also found.

With regard to VRET, in the early 1960s, psychologist Eleanor Gibson described her visual cliff experiment [17]. For this experiment, she created an experimental environment with surfaces of two different heights: one at surface level and one positioned a few feet below the first surface. A black and white checkered cloth was then draped over all surfaces. Next a large sheet of heavy clear plastic was placed to cover the entire setup, creating the perception that the floor drops sharply, even though the plastic makes the surface level physically continuous. Even though the drop was just a visual illusion, babies refused to cross a floor that appeared to drop steeply. A replication of a similar setup within a virtual environment was developed by Meehan et al. [18]. Even seasoned VR veterans had difficulty overcoming the feeling that the pit was real. Physiological signals collected from the participants during the experiments showed that the virtual cliff induced the same physiological responses as the traditional visual cliff or a corresponding real space. Slater et al. [19] also used a visual cliff scenario for comparing the behavior and subjective presence of an experimental and a control group of subjects. The control group navigated using a tracked joystick to fly along the ground plane. The experimental group navigated by walking-in-place (virtual walking). That study indicated that subjects experienced a higher sense of presence when they move by virtual walking than when they used the joystick.

With regard to the treatment of acrophobia using VRET, Rothbaum et al. [1] reported the first controlled study on VRET in which 20 participants were randomly assigned to either VRET (12 participants, 7 sessions, 35-45 minutes each) or a non-treatment control group (8 participants). VRET was found to be significantly more effective than non-treatment on all subjective measures of anxiety and avoidance. In another study, Emmelkamp et al. [2] used a within-group design, in which standard exposure in vivo was compared with VRET. Ten participants were first treated with two 1-hour sessions of VRET followed by two 1-hour sessions of exposure in vivo. VRET was found to be as effective as exposure in vivo on all subjective measures. Nevertheless, firm conclusions about the comparative effectiveness could not be drawn because of a potential order effect; all the participants received in vivo exposure after VRET. In a different study, Emmelkamp et al. [20] reproduced in the virtual environments, the places used in real exposure. Thirty-three acrophobic patients were randomly assigned to either VRET (17 patients) or exposure in vivo (16 patients). VRET and exposure in vivo consisted of three sessions of 60 minutes. VRET was found to be as effective as exposure in vivo in combating anxiety and avoidance. The improvements were maintained at a 6-month follow-up. Krijn et al. [21] designed a study to investigate the effectiveness of two different conditions of VRET, varying in the degree of presence. A CAVE was compared with a HMD. The effect of time was studied by adding a non-treatment control group. This waiting list control group was added to examine the effect of time on the severity of acrophobia. The 37 patients who participated in the study were randomly assigned across the three conditions. Therapy consisted of three sessions of one hour each. Several patients dropped out during the study because of various reasons. The analysis included in [21], for comparing the use of the CAVE/HMD, they used 14 patients for the CAVE and 10 for the HMD. For comparing VRET(CAVE/HMD) and the waiting list-condition, they used 11 patients for the waiting list and 17 patients for the VRET. Their results showed that no time effect was found for the waiting period on any measure. The participants in the non-treatment control group were randomly assigned to either CAVE or HMD after the waiting period, and their non-treatment post tests were used as pretests for the treatment conditions. The results showed that there were no differences in effectiveness between the two display systems on any measure. Presence was significantly higher in the CAVE, but this did not result in a more effective treatment. VRET, with either the CAVE or HMD, was significantly more effective than non-treatment. The results showed that the dropouts experienced significantly less presence and anxiety in the virtual environments than the completers did. They did not find correlations between presence and anxiety during the sessions. In 2007, Krijn et al. [22] also presented a study in which the effectiveness of VRET and VRET plus coping self-statements were compared. The results indicated that the addition of coping self-statements did not influence the effectiveness of treatment.

With regard to AR as an available technology for treating phobias, Juan et al. [14] and Botella et al. [15] presented the first AR system for the treatment of phobias of cockroaches and spiders. In these works, they demonstrated that, with a single one-hour session, patients significantly reduced their fear and avoidance. Initially, the system was tested in a case study [15], and then it was tested on nine patients suffering from phobia of small animals [14]. They have also proposed the use of immersive photography in an AR system for the treatment of acrophobia [16]. In this system, forty-one participants without acrophobia walked around at the top of a staircase in both a real environment and in an immersive photography environment. Immediately after their experience, the participants were given the SUS questionnaire to assess their subjective sense of presence. The users' scores in the immersive photography environment were very high. However, statistically significant differences were found between the real and immersive photography environments.

3. Description of the VR system and the AR system

In this work, we have developed two systems based on different technologies (AR and VR) that recreate the same virtual scene. The virtual scene that the two systems recreate is a room in which there is a square brown mat (2.3 meters each side). This mat is used for placing the virtual elements, which are in charge of "augmenting" the scene that produces the acrophobic situation. A hole appears in the center of the mat, the blocks of the floor fall away, and the user is at the edge of the hole; the user can also have the sensation of falling with the blocks (elevator effect).

The user wears a HMD to view both systems. In the VR system, the virtual room was modelled with 3D Studio Max using photos of the real room as textures; a joystick is used to navigate and a tracker is used to determine the user's head rotation. The room was built to be as realistic as possible and included the following features: stereo portrayal (as opposed to mono), realistic models and lighting, low lag, high frame rate, etc. These features contributed to an optimum virtual scene for inducing sense of presence.

The AR system requires a camera that is placed in front of the HMD and three markers (24 cm. each side) which are placed in the room floor to locate and orient the objects that "augment the scene". The three markers work together as one. The AR capabilities were provided by ARToolKit [23], which was incorporated into Brainstorm eStudio as a plugin. In the AR system, a physical brown mat is placed on the floor and the markers are placed over it. The VR system does not require any additional elements other than the ones already mentioned. In the AR system, the user sees the room thanks to the video that the camera placed in front of the HMD captures. When the supervisor of the test decides, the hole appears in the centre of the mat, which is mixed with the captured video. This hole is shown stereoscopically. The hole has several animations that will be described in section 2.2.

With the VR system, the user can navigate all around the scenario, and the view is stereoscopic (the room was modelled using 3D Studio Max). When the supervisor of the test decides, the user's location is changed (using an automatic trajectory from the user's position to the position where the hole appears). The animations are the same as in the AR system.

3.1. Common characteristics

Both systems were developed using Brainstorm eStudio (www.brainstorm.es) and programming in Python. Brainstorm eStudio is an advanced, multiplatform real time 3D graphics presentation tool. This tool can be defined as an interface that the programmer can use to create 3D complex visualizations using tool options only without requiring OpenGL. We developed a plugin that allowed a direct import of 3D Studio models.

The two systems have two elements in common: the floor of the room can fall away and the walls can rise up. A hole was modeled using 3D Studio Max. The hole was basically a parallelepiped with a superior surface that was placed at the level of the floor (real or virtual). The surface of this hole was a brown square which was the same color and texture as the mat that was in the real scene, so the hole was camouflaged. This hole had four dark walls and appeared to be very deep. This entire set of virtual elements was animated, and several sounds were added to try to induce a greater sense of presence in users [24]. The hole was divided into four blocks that could be moved simultaneously or independently by the experimenter at will. The present study used three animations. We designed these three animations to simulate acrophobic situations that could be used in therapy. The first one consisted of dropping three of the four blocks sequentially, leaving the user standing on the only block that did not fall away. The second animation involved dropping the four blocks sequentially, where the last block to fall was the one that the user was standing on. In the third animation, the four blocks dropped simultaneously, and the user had the sensation of falling into the hole (elevator effect). In order to obtain this effect, all the walls rose up while the rest of the virtual scene remained static. To increase the realism of the scene, several sounds were incorporated to the animations. The animations were controlled by keyboard events. Each animation had an associated key that initiated the animation. Each associated key was used to initiate or re-establish the hole taking into account its state (sunken or not). In other words, if the floor was sunk, pressing the same key that initiated the sinking, the floor state was "re-established" to its original state. Figure 1 shows the modeled room in the VR system. Figure 2 shows the mat in the VR system, and Figure 3 shows the mat and the hole in the AR system. Figure 4 shows the hole in the VR system. Figure 5 shows the elevator effect in the AR system. Figure 6 shows two of the three markers used in the AR system.

Another element that was used in the AR system is a small piece of thin yellow cardboard. This element had the function of placing the user in the right place for the animations. The user had to place this element between his or her feet. This element is shown in Figure 7. Figure 8 shows a participant using the AR system.

Fig. 1. VR system (modeled room)

Fig. 2. Mat in the VR system

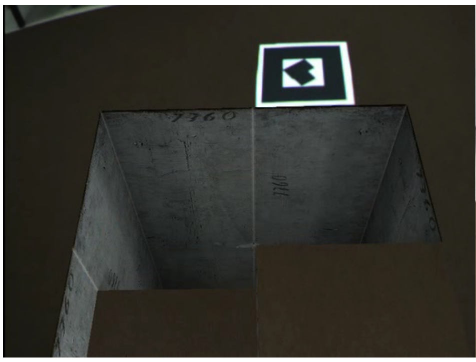

Fig. 3. Hole in the AR system

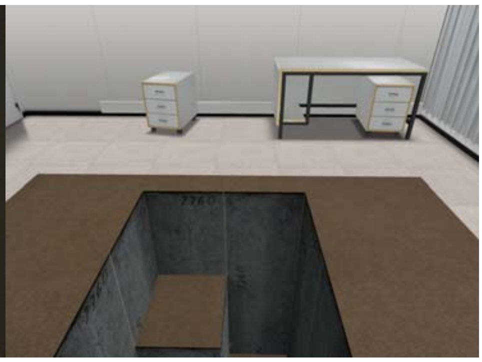

Fig. 4. Hole in the VR system

Fig. 5. Elevator effect in the AR system

Fig. 6. Two of the three markers of the AR system

Fig. 7. The thin yellow cardboard used in the AR system

Fig. 8. Participant using the AR system

3.2. Technical requirements

In our study, the systems ran on a basic Windows 2000 PC (AMD XP 2600+, 1GB RAM and NVidia Geforce 6800 128 MB).0 The experimenter could also control the position of the user and the hole animations at all times. A Dragonfly camera of Point Grey Research was used as a video source. In the AR system, the image taken from the camera is processed by the plugin of ARToolKit incorporated into Brainstorm eStudio, and the virtual elements are superposed over this image using Brainstorm eStudio facilities. A 5DT HMD (5DT Inc., 800 Hx600 V, High 40º FOV) was used as the display system. Using a screen, the experimenter could see the same scene that the user was seeing on the HMD. In order to allow the user to walk around the room, we used a GamePad (in our case the Logitech WingMan Cordless Rumblepad) and a MTx (Xsens Motion Technologies) which is a three degrees of freedom tracker that follows the user's head movements. The tracker was firmly attached to the HMD.

3.3. Participants

Twenty participants took part in the study (16 males, 4 females). The average age of the 20 participants was 28 years (S.D., 4.26). They were recruited by advertisements on the University campus, and all of them were students, scholars or employees at the Technical University of Valencia. The participants did not receive any compensation for their time. All the participants filled out the Acrophobia Questionnaire [25] in order to exclude people suffering from acrophobia.

3.4. Procedure

Participants were counterbalanced and randomly assigned to one of two conditions:

a) Participants who used the AR system first and then the VR system.
b) Participants who used the VR system first and then the AR system.

The protocol was the following. Before the user was exposed to the AR system or the VR system, he or she received instructions about how to interact with the systems during the experiment. Next, a narrative was introduced to the user. We introduced this narrative in an attempt to add meaning to the experience for the participants. We had to keep in mind that the participants were non-phobic, and, therefore, we used the narrative to try and raise their interest in the experience and encourage them to look at the scene carefully. The narrative was: "You are a guard at the Technical University of Valencia and you are on duty. You have a very important mission: there is a terrorist threat. There has been a bomb threat for this building. You have to look around carefully and inform the central guard service of any suspicious packet or bag that you locate in the rooms you have been assigned. Now you are in a room in one of the University laboratories. You have to concentrate and look for any suspicious objects. Be careful because these terrorists are extremely dangerous; they could have put booby traps in here and you may be in danger. Moreover, you have to look at everything carefully because later you have to report back to your superiors". The participants stayed in each system from 5 to 10 minutes. They first wander around the room for a few minutes, then, the person in charge of the study placed them in the area where the floor could fall away (the hole). Once the user was located in that place, the person in charge of the study controlled and executed the three animations described above. The order of execution of these animations was always the same during the experiment. After using each system (AR or VR), the participants were asked to fill out an adapted Slater et al. questionnaire [26]. In our study, the 10 questions related to the sense of presence are presented in Table 1 (the presence score is taken as the number of answers that have a score of 6 or 7). The scoring was on a scale of 1-7.

The participants were also asked to rate their anxiety level (scores from 0 = not anxious at all, to 10 = very anxious) at 6 different moments during the two experiences. These moments are presented in Table 2. At the end of the first and second experiments, some open questions related to the performed tasks were also asked.

Table 1
Presence questions

Question ID	Questions
Q1	Please rate your sense of being in a room (where 7 represents your normal experience of being in a place)
Q2	Please rate your sense of being in a room where the floor fell away from under your feet at a given moment
Q3	Please rate your sense of being in a room where the walls rose up and confined you at a given moment
Q4	To what extent were there times during the experiment when the room was reality for you?
Q5	When you think back to your experience, do you think of the room more as images that you saw (a movie, a picture), or more as somewhere that you visited?
Q6	During the experiment, which was strongest on the whole: your sense of being in the room, or your sense of being elsewhere?
Q7	Think about your memory of being in "the room". How similar is this memory to your memories of other places you have been today?
Q8	Think about your memory of when the floor "fell away". How similar is this memory to your memories of other related experiences of "falling off" or "falling down"?
Q9	Think about your memory of the walls "rising up". How similar is this memory to your memories of other related experiences of "becoming confined" or "becoming trapped"?
Q10	During the experiment, did you often think that you were actually in the room?

Table 2
Moments in which participants rated their anxiety level

Moment ID	Moment
A1	Before starting the experiment
A2	After a walk
A3	When the floor was falling away
A4	After the floor had fallen away several times
A5	When the walls rose up and participant was trapped
A6	At the end of the experiment

4. Results

To investigate whether the VR system or the AR system produced more presence, the presence scores were analyzed using paired t-test. The significance level was set to 0.05 in this analysis and in the rest of the analyses, except for the correlation between presence and anxiety. First, a sensitivity analysis to point out the effect size that the experiment could detect has been carried out. Assuming two tails, alpha=.05, power=.80, subjects=20, this experiment could detect differences as large as d = .66 (with 5% chance of type I error and 20% chance of type II error). Second, with regard to the results, none of the statistical paired t-tests that were applied to the results except one showed significant differences between the two systems. The results from question 9 showed significant statistical differences between the two systems when tests were applied. Question 9 refers to the visual effect in which the user falls with the floor, i.e., when the walls rise up. Considering that the critical value= 2.093 and $t(19)= 2.131$, a possible explanation is that this result is a type I error (an erroneous effect that could not be reliable in repeated experiments). The results are shown in Table 3. The SUS Count row shows the mean of the test count of scores of 6 or 7 for the 10 questions. The SUS Mean row uses the mean score across the 10 questions instead. The remaining rows show mean results for the individual questions. The Cohen's d column shows Cohen's effect size, d. The effect size in all tests (table 3) ranges from small to moderate according to Cohen [27]. Power column shows power analyses. Most of the values of power are low, therefore, it could be possible to have type II errors. If the sample size increased, the power would increase, and the chances of a type II error would decrease. These two last columns have been calculated using G*Power 3.1 [28]. Figure 9 shows boxplots of presence scores for the 10 questions.

The order of exposure was considered to be a critical variable since the second exposure, in a first hypothesis, might not be considered as valid a measurement as the first exposure. This is because during the first exposure, the subject can be surprised by the events (the floor falling away or the walls rising up). However, by the second exposure, they already know that these events will occur. In order to determine whether using one of the two systems first has any effect on the presence measurement for the second system, the sample was divided into two groups (the participants who used the AR system first and the participants who used the VR system first). First, a sensitivity analysis to point out the effect size that the experiment could detect has been carried out. Assuming two tails, alpha=.05, power=.80, size of group 1= 10, size of group 2= 10, this experiment could detect differences as large as d = 1.32 (with 5% chance of type I error and 20% chance of type II error). Second, with regard to the results, one-way ANOVA analyses were applied to the scores given to all questions. These analyses, Cohen's d and power analyses are shown in Tables 4 and 5. None of the statistical ANOVA tests applied to the results except one showed significant differences between the two systems. The situation in which the order affected the results was when the AR system was used with question 7 (Q7). In this case, the results were better when the order of exposure was VR first and then AR. Two possible explanations can be given. First, based on what the participant was doing, Q7 result could be because the questionnaire was filled out just after using the AR system and it was done in the exact place where the test took place. Therefore, the participant remembered better what he or she saw at that moment. Second, based on the alpha value, tables 4 and 5 report 20 tests, each with a 5% chance of a type I error (alpha=.05). Out of 20 such tests, we could expect to find one type I error on average. Therefore, Q7 in Table 5 could easily be a type I error. Figure 10 shows boxplots of the VR system used first and second for presence scores. Figure 11 shows boxplots of the AR system used first and second for presence scores.

Table 3
Means (SD) of the VR system and the AR system, and paired t-tests for presence scores. d.f. 19, '**' indicates significant differences.

Question	VR Post-test	AR Post-test	t	p	Cohen's d	power
SUS Count	3.25(3.63)	3.65(3.03)	-0.657	0.519	0.15	0.10
SUS Mean	4.8 (1.08)	4.66 (1.25)	0.814	0.426	0.18	0.12
Q1	5.25(1.25)	5.20(1.64)	0.237	0.815	0.05	0.06
Q2	4.6(1.64)	4.4(1.57)	0.847	0.408	0.19	0.13
Q3	4.5(1.70)	4.1(1.65)	1.285	0.214	0.29	0.23
Q4	4.55(1.43)	4.7(2.13)	-0.318	0.754	0.07	0.06
Q5	4.8(1.28)	4.45(1.73)	1.022	0.320	0.23	0.16
Q6	5.45(1.43)	5.2(1.77)	0.665	0.514	0.15	0.10
Q7	4.9(1.07)	5.1(1.29)	-0.777	0.447	0.17	0.12
Q8	4.5(1.67)	4.2(1.51)	0.880	0.390	0.20	0.13
Q9	4.4(1.47)	3.95(1.32)	2.131**	0.046**	0.48	0.52
Q10	5.05(1.39)	5.25(1.65)	-0.507	0.618	0.11	0.08

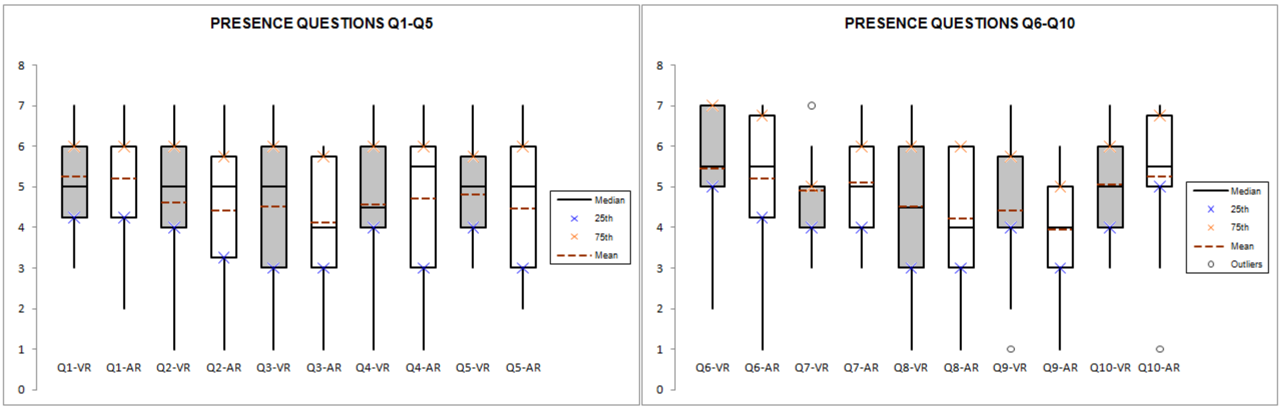

Fig. 9. Boxplots of the VR system and the AR system for presence scores

Table 4
Means (SD) of the VR system used first and second, and one-way ANOVA analysis of presence scores. d.f. 1, 18.

	VR – 1st	VR-2nd	F	p	Cohen's d	power
Q1	5.2(1.14)	5.3(1.42)	0.030	0.864	0.08	0.05
Q2	4.1(1.45)	5.1(1.73)	1.965	0.178	0.63	0.26
Q3	4.3(1.49)	4.7(1.95)	0.266	0.613	0.23	0.08
Q4	4.3(1.70)	4.8(1.14)	0.597	0.450	0.35	0.11
Q5	4.7(0.95)	4.9(1.60)	0.116	0.737	0.15	0.06
Q6	5.6(1.08)	5.3(1.77)	0.210	0.652	0.21	0.07
Q7	5.0(0.82)	4.8(1.32)	0.167	0.688	0.18	0.07
Q8	4.5(1.58)	4.5(1.84)	0	1	--	--
Q9	4.3(1.25)	4.5(1.72)	0.089	0.769	0.13	0.06
Q10	4.7(1.16)	5.4(1.58)	1.278	0.273	0.51	0.19

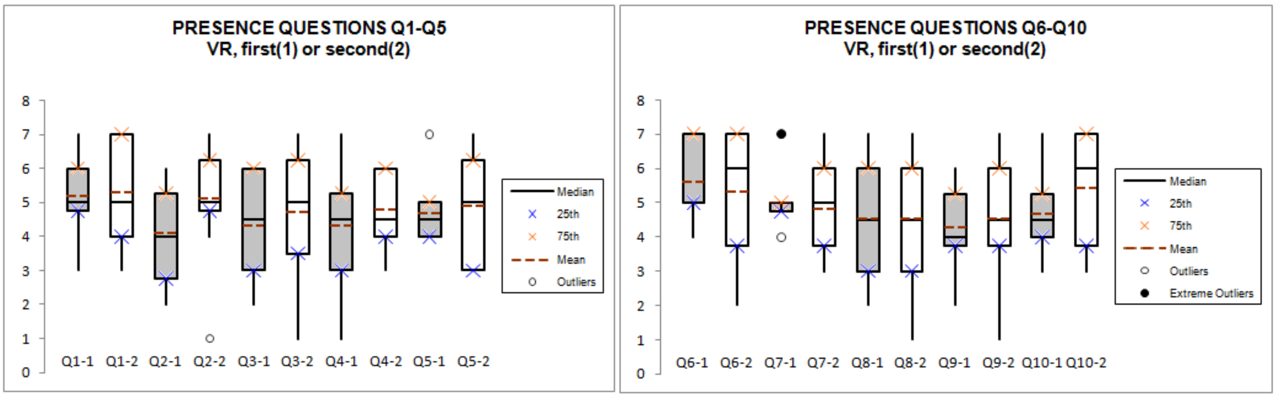

Fig. 10. Boxplots of the VR system used first and second for presence scores

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Table 5
Means (SD) of the AR system used first and second, and one-way ANOVA analysis of presence scores. d.f. 1,18. '**' indicates significant differences

	AR – 1st	AR-2nd	F	p	Cohen's d	power
Q1	4.8(1.81)	5.6(1.43)	1.2	0.288	0.49	0.18
Q2	4.5(1.72)	4.3(1.49)	0.077	0.784	0.12	0.06
Q3	4.5(1.58)	3.7(1.70)	1.185	0.291	0.49	0.18
Q4	4.3(2.45)	5.1(1.79)	0.694	0.416	0.37	0.12
Q5	4.2(1.93)	4.7(1.57)	0.404	0.533	0.28	0.09
Q6	5.3(1.83)	5.1(1.79)	0.061	0.808	0.11	0.06
Q7	4.5(1.43)	5.7(0.82)	5.268**	0.034**	1.03	0.59
Q8	3.9(1.66)	4.5(1.35)	0.783	0.388	0.40	0.13
Q9	4.0(1.41)	3.9(1.29)	0.027	0.871	0.07	0.05
Q10	4.9(2.23)	5.6(0.70)	0.895	0.357	0.42	0.15

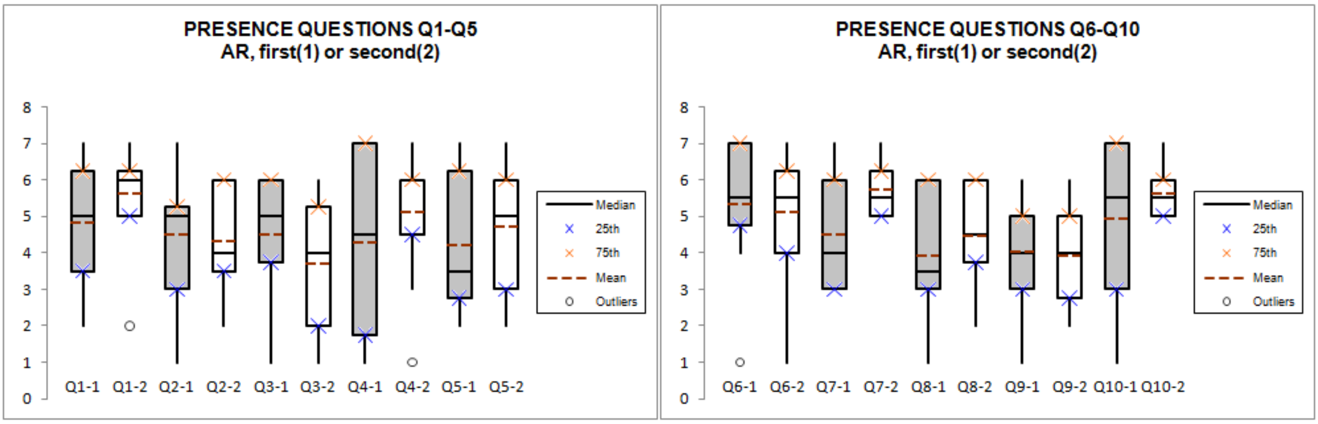

Fig. 11. Boxplots of the AR system used first and second for presence scores

For the level of anxiety, the participants were asked to rate their anxiety level (scores from 0 = not anxious at all, to 10 = very anxious) at 6 different moments (A1-A6). Paired t-tests were used to analyzed the data. Table 6 shows these analyses, Cohen's d and power analyses. First, the participants did not show hardly any anxiety. One possible reason for this is that the participants did not suffer from acrophobia. The results from Table 6 show that there were no significant differences in anxiety in all the situations. Figure 12 shows the boxplots of anxiety scores at the 6 different moments for the AR system, and Figure 13 shows the boxplots of anxiety scores for the VR system.

Table 6
Means (SD) of the VR system and the AR system, and paired t-tests for anxiety levels. d.f. 19.

	VR	AR	t	p	Cohen's d	power
A1	1.05(0.22)	1.10(0.31)	-0.567	0.577	0.13	0.08
A2	1.20(0.52)	1.10(0.31)	0.698	0.494	0.16	0.10
A3	2.10(1.37)	2.25(1.48)	-0.334	0.742	0.08	0.06
A4	1.70(1.08)	1.85(1.09)	-0.411	0.685	0.09	0.07
A5	2.50(2.09)	2.30(1.90)	0.319	0.753	0.07	0.06
A6	1.35(0.75)	1.35(0.75)	--	--	--	--

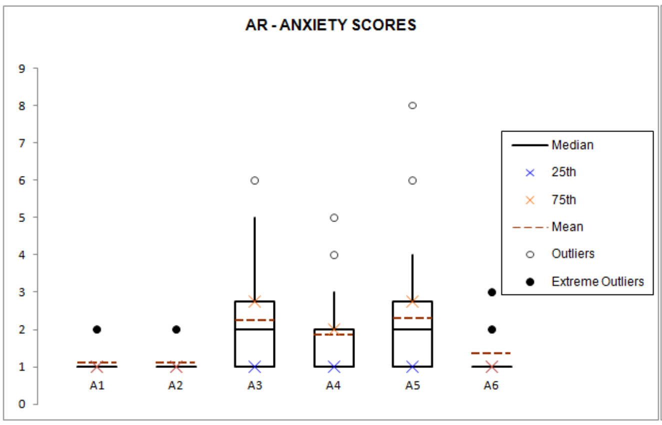

Fig. 12

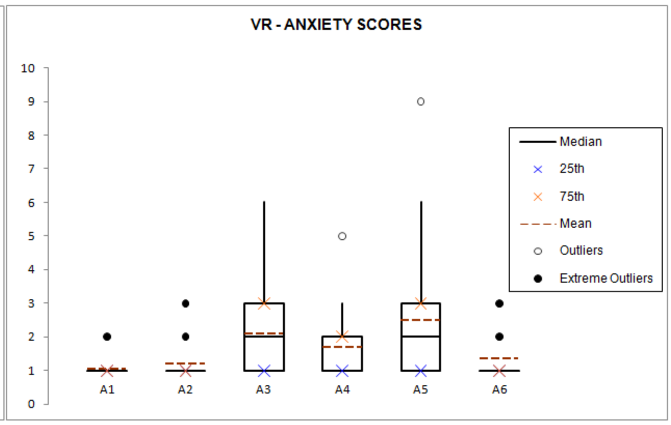

Fig. 13

Fig. 12. Boxplot of anxiety scores at the 6 different moments for the AR system. **Fig. 13.** Boxplot of anxiety scores at the 6 different moments for the VR system

We have also compared the anxiety level at the moment before starting the experiment with the anxiety level during the different stages of the experiment using the two systems. These results using paired t-tests, Cohen's d and power analyses are shown in Tables 7 and 8. The results indicate that there is a significant difference between them (except at two moments). The two moments in which there were not significant differences were: the moment after a walk and at the end of the experiment. The first situation can be explained because no stimulus that provokes anxiety has yet been produced (the floor falling). The second situation can be explained because the experiment has finished, after having experienced all the effects that provoke anxiety; therefore the participant is relaxed.

Table 7
Comparison of the initial level of anxiety with the level of anxiety in steps 2-6 of the AR system using paired t-tests. d.f. 19. '**' indicates significant differences.

Table 8
Comparison of the initial level of anxiety with the level of anxiety in steps 2-6 of the VR system using paired t-tests. d.f. 19. '**' indicates significant differences.

	t	p	Cohen's d	power		t	p	Cohen's d	power
A2	--	--	--	--	A2	-1.831	0.083	0.41	0.41
A3	-3.437**	0.003**	0.77	0.90	A3	-3.566**	0.002**	0.80	0.92
A4	-3.000**	0.007**	0.67	0.81	A4	-2.795**	0.012**	0.63	0.76
A5	-2.897**	0.009**	0.65	0.79	A5	-3.142**	0.005**	0.70	0.85
A6	-2.032	0.056	0.46	0.49	A6	-2.042	0.055	0.46	0.49

Table 7. Table 8.

For the relationship between anxiety and presence, we have used Pearson's correlation. The null hypothesis is that the correlation coefficient comes from a population in which the correlation is 0. In order to determine if there is correlation, we have checked if the correlation coefficient is within the sample distribution specified by the null hypothesis with different probabilities. Table 9 shows the relationship between anxiety and presence when participants used the AR system/VR system either first or second. In this case, we have correlated the anxiety in moments: A2, A3, A4 and A5 with the presence questions related to these moments, Q1, Q2, Q3, Q8 and Q9. We have added a '*' sign after values indicating where the correlation is higher (*). The results in Table 9 show correlations (direct or reverse) between anxiety and presence; however, in all cases, the values of α (significance level) were very high. The α values range from 0.11 (maximum) to 0.68 (minimum). In the VR system with the relationship A2-Q1, the correlation coefficient of Pearson is equal to zero. This does not necessarily imply that there is no correlation between presence and anxiety. It can exist, but it will not be linear. It is not possible to establish that the relationship between presence and anxiety is greater in one system or the other since each system shows the greatest correlations in three out of six situations. Nevertheless, all the correlation coefficients are near 0, indicating that the correlations are very low.

Table 9
Pearson's correlation between anxiety and presence

	AR system			VR system		
	r_{xy}	t	α	r_{xy}	t	α
A2-Q1	0.17	0.72	0.48*	0.00	0.00	-
A3-Q2	0.09	0.39	0.70	0.10	0.42	0.68*
A3-Q8	0.12	0.50	0.62	0.21	0.90	0.38*
A4-Q8	0.12	0.49	0.63	0.20	0.88	0.39*
A5-Q3	0.19	0.83	0.42*	0.16	0.70	0.49
A5-Q9	0.36	1.66	0.11*	0.05	0.22	0.83

In the open questionnaire that was fill out for all participants when they have used the two systems, some of the questions and answers were the following:

1.- What "puts you" into the virtual scene more? Most of the participants answered "the stereoscopic presentation of the scene". Others answered "the way of navigating in the VR system".
2.- Do you think it is important that you can see your feet next to the hole where the floor falls away?. Fifteen participants answered yes (75%). Those participants were also asked to score this importance from 1 = Not very important, to 10 = Very important. The mean and standard deviation was: 7.87(1.51). The results indicate that participants consider it important to see their feet next to the hole where the floor falls away.

5. Conclusions

We have developed an AR system and a VR system that include acrophobic scenarios. The results show that the levels of presence and anxiety between VR and AR are equivalent within a bound of d = .66. To our knowledge, this is the first work in which both an AR system and a VR system that include acrophobic scenarios have been compared, and the second work in which AR has been used for the development of acrophobic scenarios (the first work is [16]). For the sense of presence, paired t-tests and one-way ANOVA analyses did not show significant differences between the two systems, with an average score of about 4.66 for the AR system for all the questions on a scale of 1 to 7 (Table 3). For the VR system, the average score was about 4.8 on the same scale. However, the analysis of Cohen's effect size and power suggest a larger sample for decreasing the chances of a type II error. This study has also tried to analyze whether using one of the two systems first had some effect on the presence measurement given for the second system. None of the statistical ANOVA tests applied to the results except one showed significant differences between the two systems. For the anxiety level, paired t-tests did not show significant differences between the two systems. The results also show that there is a significant difference between the level of anxiety felt at the moment before starting the experiment and the level felt during the different stages of the experiment. The results indicate that there is a significant difference between them (except at two moments). The two moments in which there were not significant differences were: the moment after a walk and at the end of the experiment.

This is not the first study in which correlations between anxiety and presence have been studied using HMDs and VR [9, 12, 13]. Schuemie et al. [9] also used acrophobic environments. In the Schuemie et al. study, all the participants did not suffer from strong acrophobia, but at least two of them did. They used the same HMD and three different virtual scenes. In a more recent study, Bouchard et al. [12] used anxious scenes for patients suffering from snake phobia. They used a HMD and compared three different immersions. In another of our studies [13], if we consider only the results related to the HMD, the mean for the level of presence was lower (about 3.6). The initial anxiety level was also lower, but the scores for the steps during the experiment showed higher values than those obtained in this paper. The correlation between presence and anxiety were greater than in this paper, with much lower values for the significance level.

Due to the fact that participants did not find significant differences between the VR system and the AR system, our opinion is that they perceived both systems as similar. Therefore, the participants' sensations are the same, but some advantages are achieved: first, with AR, the time and cost for developing the virtual scene is reduced because the scene is the real one; second, the participants can see their own hands, feet, and so on, whereas VR only simulates this experience, and participants in our experiment considered it to be important to see their feet next to the hole where the floor falls away 7.87(1.51), on a scale of 1-10.

We believe that AR can be used as an alternative for treating acrophobia based on the results from this work and our previous results [13] as well as the results of other research groups related to VR [9, 12] and VRET [1, 3]. This is an hypothesis that should be corroborated in future works.

With regard to other future works, first, self-reporting is known to have a number of limitations. The first limitation is that the questionnaires only offer a subject's impression of presence post-experience which can be misleading. The second limitation is that since the experimenter is asking the subject to verbalize his or her level of presence, this could have an impact on his or her sense of presence. In this work, we have chosen SUS because of its popularity for facilitating comparisons with other studies. However, there are several other questionnaires available (e.g. ITC-SOPI [29]), even physiological measures [18] or methods in which the measure depends on the data collected during the experience (e.g. [30] in which the number of transitions from virtual to real is counted, and a probabilistic Markov chain model can be constructed to model these transitions). Since only the answers to the questions have been taken into account in this experiment, future work could take into account some of these other measures. All the measures obtained in this new work could be analysed using logistic regression [31]. Second, as the navigation is different in the two systems (joystick flying in the VR condition and actual walking in the AR condition), this could contribute to a larger difference between these environments and it could also affect presence. Therefore, a better comparison between AR and VR could be a replicated experiment in which participants walk in both environments. Several experiments (e.g. [32]) have found that walking through a virtual environment produces much more presence than flying. In order to determine how this affects navigation difference, a new study could also be performed. Finally, a different design could be considered, using a between-subjects design in which participants see either only the AR system, or only the VR system.

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