An Augmented Reality System for the Treatment of Acrophobia: The sense of presence using immersive photography

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Abstract
This paper describes an Augmented Reality (AR) system for the treatment of acrophobia. First, the technical characteristics of the first prototype are described. Second, the capacity of the immersive photography used in the AR system to provoke sense of presence in users is tested.

Forty-one participants without fear of heights, walked around a staircase in both a real environment and an immersive photography environment. Immediately after their experience, participants were given the SUS questionnaire to assess their subjective sense of presence. The users' scores in the immersive photography were very high. Results indicate that the acrophobic context can be useful for the treatment of acrophobia. However, statistically significant differences were found between real and immersive photography environments. Specifically, the immersive photography environment was not confused with reality since data showed that SUS distinguished between the real and immersive photography experiences.

Keywords--- Acrophobia, Augmented Reality, immersive photographs, virtual therapy

1. Introduction

In an Augmented Reality (AR) system, users see an image comprised of a real image and virtual elements that are superimposed over it. The most important aspect in AR is that the virtual elements add relevant and helpful information to the real scene. AR can be a successful tool in many fields since it can be applied anywhere where the information superimposed on the real world can help the user; psychological therapy is one of these fields.

This paper presents an AR system for the treatment of acrophobia. Acrophobia is an intense fear of heights and consequent avoidance of situations 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 fear any situation that involve heights, even when other people are in those 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. After a time, habituation occurs and the fear gradually diminishes.
The present paper presents the first system that uses AR to treat this type of phobia. However, this is not the first system to treat acrophobia with technologies. Schneider (1982) carried out a pioneer work for the treatment of this specific phobia. Schneider's study is a case report that describes reverse viewing through binoculars to magnify apparent height during *in vivo* exposure. Later, more sophisticated, technologies like VR systems have shown that this tool is effective in the treatment of acrophobia (e.g., North, North, Coble, 1996; Jang et al., 2002). Several experiences comparing the effectiveness of VR with in vivo exposure have also been reported (Rothbaum, 1995; Emmelkamp et al., 2002). These studies have shown that VR exposure is as effective as in vivo exposure.

The number of studies showing the efficacy of VR environments as therapeutic tools for the treatment of several psychological problems (fear of flying, agoraphobia, claustrophobia, eating disorders, etc.) has increased in the last few years. Although AR and VR share some advantages over traditional treatments, AR in some cases also presents additional advantages over VR (Botella et al., 1998; 2004). In the specific case of acrophobia, to create different locations of high quality is extremely costly in VR. Furthermore, although VR applications could include avatars that simulate participants' bodies, participants cannot see their own feet, hands, etc. whereas in AR application they can.

Botella et al. (2005) and Juan et al. (2005) presented an AR system for treating phobias of small animals (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, and then was tested on nine patients suffering phobia of small animals.

Given that this first application proved to be effective, we believe that AR could be also useful for the treatment of acrophobia; we designed an AR system for this problem. The first aim of this paper is to describe the technical characteristics of this AR system.

Before using this system with people who suffer from acrophobia, the capacity of the AR environments to evoke sense of presence in the users should be tested. It is often assumed that the sense of presence moderates successful outcomes of VR treatment (Wiederhold & Wiederhold, 2000). However, in order to determine whether or not presence serves as a mediator of the relationship between virtual environments and the therapeutic efficacy, four "tests of mediation" are needed (Keogh, Bond and Flaxman, in press). Following Baron and Keany (1986), it is necessary to establish that (see Figure 1): a) virtual environments are correlated with the mediator, that is, presence (path a); b) the mediator, (presence), is correlated with the outcome therapy (path b); c) virtual environments are efficacious as a therapeutic tool (path c); and d) the relationships between virtual environments and therapeutic efficacy should be non-significant when the mediator (presence) is completely controlled in the analysis.

Therefore, the second aim of this paper is to offer some data about this mediator effect of presence. The specific objective is to offer data about "path a", namely, the capability of the virtual environment to evoke presence. Future works will determine whether requirements of path b and c are also fulfilled. Regarding this second aim, this paper analyzes the sense of presence experienced by non-clinical users while they navigate through an immersive photograph of a staircase. According to Usoh et al. (2000) a methodology for measuring the efficacy of a virtual environment is the extent to which participants cannot discriminate between the VE and a real environment. In the present study, subjective presence measurements collected after exposure to a real environment and an immersive photography environment (using the AR system) are compared.
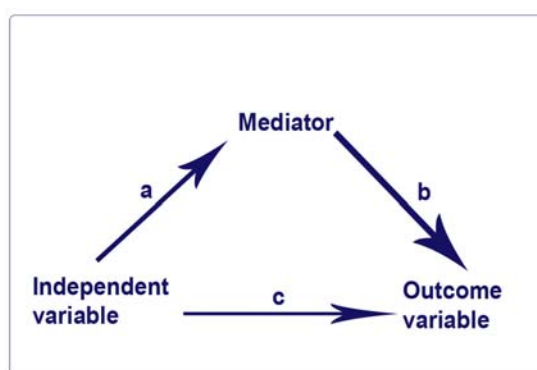

Figure 1 A three-variable mediation model

2. Technical characteristics of the AR system

a) The creation of immersive photographs

Immersive photography is a technique widely developed during the 1990s (Chen, 1995; Chiang, 1997), which has been used to create VR environments; however, it has not been included in an AR system thus far. For example, VideaLab Research group (videalab.udc.es) has used immersive photography in several VR projects. The EC funded project, Benogo (www.benogo.dk) used photo realistic 3D real-time visualisation of real places to enable people to experience presence. Two of these exploratory studies are: in amongst the plants and sitting on the stairs. The first used a photo-realistic re-creation of a glasshouse in the Prague botanical garden. The second used a photo-realistic re-creation of an elegant stairway and landing at the Technical University of Prague. The idea of these studies is similar to ours, but they did not compare the photo-realistic place with the real place and the measures and protocol used are different from ours.

In the immersive photography technique, the entirety of a space is captured from a single point and digitally processed to create a 360-degree photograph. There are panoramic visualization systems like QuickTime VR (Chen, 1995) or Surround Video (Surround Video, 1996). These systems are based on 360º cylindrical panoramic static images. When an immersive photograph is viewed, it appears to be a standard two dimensional photograph, but when manipulated by users, it spins 360 degrees in any direction. This allows users to look around a terrace, for example, in any direction that they choose. They can look at the view out the balustrade, the hammock to the right, or the sky over them. They can even turn all the way around and look at all the details.

The steps that were followed to create a 360-degree photograph that was suitable to be mapped as texture into the development tool were: 1) to take a 180-degree photograph, 2) to retouch the photograph, 3) to create a 360-degree photograph, and 4) to assign a transparency to the 180-degree white image.
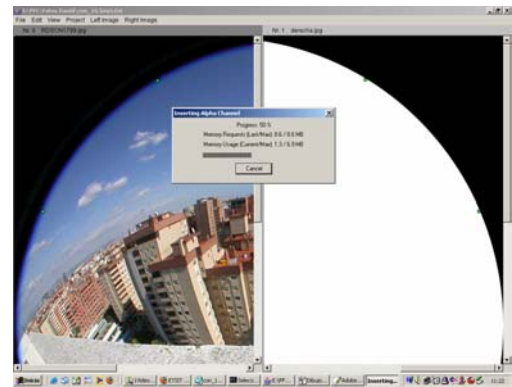
1. Taking a 180-degree photograph

A digital color Coolpix 4500 Nikon Camera and a FC-E8 Fisheye converter were used. The digital camera together with the Fisheye converter covers a field of view of over 180 degrees and is capable of capturing a full spherical panorama.

Photographs of different locations were taken. In each location, we took three parallel photographs for each eye. The process was the following: The photographer was located next to the balustrade (if there was one), or as close as possible to the edge. The photographer took a photo for the left eye with a distance ranging from 5 to 7 centimeters; then, 3 more photographs for the right eye were taken. Therefore, the users can choose among the images in order to adjust the vision to the distance between their eyes. Later, the photographer moved one meter towards the right, maintaining parallel position with respect to the edge of the location. Then the photographer took another photograph and repeated the process. Once this was done, there were three parallel 3D immersive photographs that were one meter apart. Figure 2 shows this process.
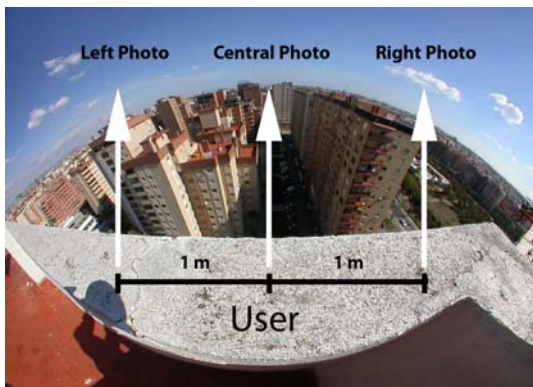
(2)   (3)

Figure 2 Process of taking 3 immersive photographs

Figure 3 Creation of a 360-degree image using PTSitcher

2. Retouching the photograph

The photographs were retouched using Adobe Photoshop. In this step, undesirable information was removed from the image (such as the photographer's feet).

3. Creating a 360-degree photograph

Because the photograph was 180 degrees, a new 360-degree image had to be created. In our system, we created a 360-degree image by sewing together the 180-degree photograph and a transparent 180-degree image. We used PTStitcher to achieve this. This program belongs to the software Panorama Tools of Helmut Dersch (fh-furtwangen.de/~dersch). Figure 3 shows an image of this process.

4. Assigning a transparency to the 180-degree white image

The 180-degree white image had to be converted into a transparent image. Otherwise, the white 180-degree image would cover the users' positions and they would not see their bodies. The system maps this new image as a 360-degree texture. This process was performed using Adobe Photoshop.

b) Development tool

The application was developed using Brainstorm eStudio (www.brainstorm.es), an advanced, multiplatform real time 3D graphics presentation tool. We included ARToolKit (Kato, Billinghurst, 1999) into Brainstorm as a plugin which was programmed in C++. ARToolKit is an open source library programmed in C that allows programmers to easily develop AR applications. It was developed at Washington University by Kato and Billinghurst. The required elements of the application are: a USB or Firewire camera, and a "marker". Markers are white squares with a black border inside of which are symbols or letter/s. ARToolKit uses computer vision techniques to obtain the position and orientation of the camera with respect to a marker. Virtual elements are drawn over these markers.

By including ARToolKit capabilities in Brainstorm eStudio, we had AR options in a 3D graphic presentation tool, which offered many advantages. ARToolKit recognizes the markers and obtains the position and orientation where virtual 3D objects must be placed. Brainstorm eStudio uses this information to draw the virtual 3D objects. This plugin can work with more than one marker. The position and orientation of each marker is assigned to as many different 3D objects in Brainstorm eStudio as needed. The plugin is loaded as a dynamic library (dll) in execution time.

c) Immersive Environments

The system includes different locations/levels. These locations were chosen by expert psychologists. We attempted to select typical locations that a therapist uses in the treatment of acrophobia, including:

images taken from a window of a building (located on the first, second, third, fourth, fifth and fifteenth floors), view of a stairwell from the second and third floors, view of a staircase from a terrace situated on the second floor, view of a dam (both sides) and images taken from a terrace located on the second and third floors.

First, the system shows the first level (the minimum height). Changing from one level to the next can be accomplished using the option menu or control keys. The system uses five different markers that ARToolKit recognizes. If the camera focuses on the central marker, the system shows the central photograph of the selected level on this central marker. If the camera is focused to the left of this central marker (left markers), the system will show the left photograph of the selected level. The same occurs for the right photograph. The immersive photograph is mapped as a spherical texture on a sphere. The appropriate image of this sphere is determined by the orientation of the user (information given by the tracker) and is shown over the marker. Therefore, the marker the camera focuses on determines the immersive photograph that must be shown at the selected level. The part of this photograph to be shown is determined by the tracker.

Figure 4 shows the initial position and orientation of the user with respect to the sphere. If the user rotates his/her head 90 degrees up or down, the user will see part of the immersive photograph. If the user rotates his/her head more than 90 degrees up or less than -90 degrees down, the user will see part of the immersive photograph and part of the image taken by the Firewire camera (real image). Figure 5 shows an example taken during the execution of the application with an immersive photograph of a dam. In this figure, the virtual elements are the mapped images (immersive photographs), and the real images are the floor of the room and the feet of the person using the system.
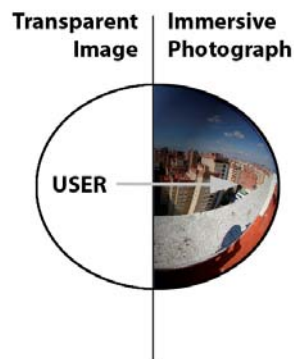
(4)   (5)

Figure 4 User's view inside the 360-degree sphere

Figure 5 A user is partly inside and partly outside of the immersive photograph of a dam

d) Hardware

As mentioned before, for the AR-acrophobia system, immersive photographs were taken using a digital color Coolpix 4500 Nikon Camera and the FC-E8 Fisheye converter. The system can run on a typical PC, without any special requirements. The real world was captured using a Dragonfly camera (Drag-Col-40, Point Grey Research). The AR image was shown in a Head Mounted Display (HMD) and on a monitor. Thus, the therapist had the same visualization as the patient. We used 5DT HMD (5DT Inc., 800 H x 600 V, High 40º FOV). The camera was attached to the HMD so that it focused wherever the patient looked. The system also had to know the position of the patient's head in order to spin the immersive photograph according to the patient's head movements. We used a MTx tracker (Xsens Motion Technologies) to detect the patient's head rotation, which was attached to the HMD.

3. Study

The aim of this study is to test the efficacy of immersive photography to induce sense of presence in users. For this purpose, subjective presence measurements collected after exposure to a real environment and in an immersive photography environment were compared.

The study included 41 participants, 28 males and 13 females. They were recruited by advertisements in the University campus, and all of them were students, scholars or employees at the Technical University of Valencia (age range from 17 to 45). All participants filled out the Acrophobia Questionnaire (Cohen, 1977) in order to exclude people suffering from acrophobia.

The scenario was a staircase. There were two versions of this space: the real space and the immersive photograph of this space (see Figures 6 and 7). The space was a terrace of the Applied Computer Science Superior Technical School building, from which a staircase could be seen. Participants using the AR system wore the camera, the tracker and the HMD.

Participants were counterbalanced and assigned to one of two conditions: a) Participant first visited the real space and later the immersive photography environment, b) Participant first visited the immersive photography environment space and later the real one. Before starting to walk in the real or immersive photography environment, a narrative was introduced so that the experience had more meaning and interest for them. The narrative was: "You are going to be in a place where there is a staircase. You are a security guard at the Technical University and you are on duty. You have to pay full attention to all details of the location because later we will ask you some questions about it. You are here to watch out for burglars who may enter or leave the building and to notify the security center". Participants stayed seven minutes in both the immersive photography environment and the real place.

After visiting each place (real or virtual), participants were asked to fill out the Slater et al. questionnaire (Slater et al., 1994) (SUS). In the SUS, direct references to an experience within a virtual environment were changed to refer to the "staircase". Hence the same questionnaire was used for both environments (real and immersive photography) and participants filled it out twice (after visiting each place). The 6 questions related to presence were as follows (the presence score is taken as the number of answers that have a score of 6 or 7).

1. Please rate *your sense of being in this* space within a staircase, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a place*.
I had a sense of "being there" in the space within a staircase: 1. Not at all ... 7. Very much.

2. To what extent were there times during the experience when the space within a staircase was the reality for you?
There were times during the experience when the space within a staircase was the reality for me: 1. At no time ... 7. Almost all the time.

3. When you think back about your experience, do you think of the space within a staircase more as *images that you saw*, or more as *somewhere that you visited*?
The space within a staircase seems to me to be more like: 1. Images that I saw ... 7. Somewhere that I visited.

4. During the time of the experience, which was strongest on the whole, your sense of being in the space within a staircase, or your sense of being elsewhere?
I had a stronger sense of: 1. Being elsewhere ... 7. Being in the space within a staircase.

5. Consider your memory of being in the space within a staircase. How similar in terms of the *structure of the memory* is this to your memory structure of other *places* you have been today? By "memory structure" consider things like the extent to which you have a visual memory of the space within a staircase, whether that memory is in color, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such *structural* elements.
I think of the space within a staircase as a place in a similar way to other places that I've been today: 1. Not at all ... 7. Very much.

6. During the time of the experience, did you often think to yourself that you were actually in the space within a staircase ?

During the experience I often thought that I was really standing in the space within a staircase: 1. Not very often ... 7. Very much.

The SUS questionnaire had a 'free response' final question: "Please write down any further comments that you wish to make about your experience."

4. Results

Results are shown in Table 1. The SUS Count column shows the mean of the SUS count of 6 or 7 scores amongst the 6 questions. The SUS Mean column uses the mean score across the 6 questions instead. The remaining columns show mean results for the individual questions.

GROUP	SUS Count	SUS Mean	Q1	Q2	Q3	Q4	Q5	Q6
Real environment	5.9 ± 0.49	6.93±0.29	6.9±0.3	6.9±0.5	6.9±0.6	6.9±0.2	6.9±0.3	6.9±0.2
Immersive photography environment	2.73±2.05	5.29±1.09	5.6±1.2	5.3±1.3	5.3±1.4	5.5±1.4	5.1±1.2	5.1±1.2
Student t	9.68 p<.000	9.10 p<.000	6.74 p<.000	7.88 p<.000	6.45 p<.000	6.43 p<.000	10.09 p<.000	8.23 p<.000

Table 1. Means and Standard Deviations of Questionnaire Scores

The data obtained in the immersive photography environment indicate that users achieved a high degree of presence in the environment (mean scores over 5 in a scale from 1 to 7). However, all statistical tests applied (Student t tests) showed significant differences between the two environments for all measures: each of the individual responses, the mean total score obtained in the SUS, and the SUS Count score. That is, the immersive photography environment was not confused with reality since data show that SUS distinguished between the real and immersive photography experiences.

With the aim of knowing whether previously visiting one of the two environments had some effect on the presence measurement in the second environment, the sample was divided into two groups (participants who had first visited the real space and participants who had first visited the immersive photography environment) and Student's t tests for the scores given to all questions were applied. No significant statistical differences were found (see Table 2), so the order of the visit did not influence the users' scores on presence.

		Q1	Q2	Q3	Q4	Q5	Q6
Real Environment	1real-2AR(*)	7(0)	7(0)	7(0)	7(0)	7(0)	7(0)
	1AR-2real(+)	6.9(0.4)	6.9(0.6)	6.7(0.7)	7.9(0.2)	6.8(0.4)	6.9(0.2)
Immersive photography environment	1real-2AR	5.7(1.4)	5.5(1.3)	5.4(1.7)	5.5(1,4)	5.1(1.35)	5.3(1.4)
	1AR-2real	5.4(1.1)	5(1.1)	5.2(1.2)	5.6(1.4)	5.1(1)	4.9(1.4)

Table 2. Means and Standard Deviations of the scores obtained in the Questionnaire. Comparison according to the order of presentation. (*) Scores obtained by participants who first visited the real environment and then the immersive photography environment. (+) Scores obtained by participants who first visited the immersive photography environment and then the real space.

Figures 8 and 9 show a participant visiting the real and the immersive photography environments, respectively.

Figure 6 Real environment

Figure 7 Immersive photography environment

Figure 8 Participant in the real place

Figure 9 Same participant of Figure 7 using the AR system

5. Conclusions

From the results two main conclusions can be drawn. Firstly, SUS is a measure capable of discriminating between experiences that take place in both a physical environment and a "virtual" environment. Secondly, it seems that immersive photography provokes a high level of presence in users, although not as optimally as the real world.

Regarding the first conclusion, these data are not in accordance with those obtained by Usoh, Catena, Arman, and Slater (2000). These authors found non significant differences in presence measures between real and virtual environments. These authors concluded that questionnaires may be useful when all participants experience the same type of environment. However, their utility is doubtful for the comparison of experiences across environments, such as immersive virtual compared to real, or desktop compared to immersive virtual. However, our results show that the SUS measure would pass what Usoh has termed the "reality test" since the rated sense of presence is higher in the real environment. In fact, all participants except two gave maximum scores to all questions in the real world. That is, for 90% of participants, reality is the optimal experience of presence.
There are some differences between our study and the work made by Usoh et al. which could justify these differences. First, the number of participants: there were 41 in our study and only 20 in Usoh et al's work (and by using a *between subjects* design, the number of participants per group was further reduced to 10). On the other hand, it should be noted that in Usoh et al.'s study the scores on sense of

presence given by the participants in the real world were very low (mean of 4.4), while in our study these scores were the highest (mean of 6.9). The same occurs in the case of simulated worlds; in Usoh et al.'s study the presence scores were around 3.8, while in our work they were 5.29. It may be that the differences are due to the use of different real world scenarios. The Usoh et al.'s real world scenario was a place inside a building (an office), while in our work the real space was outside. In any case, we think that more data will be needed in order to draw firmer conclusions about the utility and reliability of self-report questionnaires as measures of the sense of presence.

Regarding the second conclusion, data show that immersive photography provokes a high level of presence in users. However, presence in this mediated environment is not as optimal as in the real world. This study reveals the importance of establishing criteria in order to delimit when an environment has evoked a "sufficient" sense of presence. That is, we need criteria for what intensity or which scores have to be achieved in order to affirm that an environment evokes presence in a user. This is crucial, specially in the field of therapeutic applications, given that the concept of presence could be contemplated as a pre-requirement of the virtual environments related to ecological validity: "ecological validity refers to the extent to which the environment experienced by the subjects in a scientific investigation has the properties it is supposed or assumed to have by the experimenter" (Bronfenbrenner, 1977).

Nevertheless, what has usually been done in clinical studies has been to take the aspect related to presence for granted and to analyze whether the environment was able to activate the target emotion, such as the fear response when coping with the phobic situation by using clinical samples (Rothbaum et al 1995, 1996; Botella et al. 1998; 2000; 2004), or to analyze the relationship between presence and emotion elicited in users (Baños et al., 2004). In the same way that the telepresence experience was initially thought to improve task performance in the remote environment (Minsky, 1980), it has generally been thought that a key reason to take presence into consideration "concerns its potential to affect the emotions, judgment, learning, task performance, and so forth, of those who experience it" (Reeves and Lombard, 2005). Unfortunately, this has not been studied in a systematic way. In our view, this issue is notably important (at least regarding clinical applications). It might be that the relationship between presence and therapeutic efficacy it is not always clear and simple, that is, a positive and linear relation. In our clinical experience we have already observed that a very negative emotion evoked a lesser degree of presence, for example. It might be that this relationship depends on different factors which should be tested in controlled studies if we want to progress in the application of these developments in the field of clinical psychology.

In summary, besides the description of the AR system, the aim of this work has been to analyze whether immersive photography is able to generate a high sense of presence in nonclinical participants. Once this is tested, the second step will be to study the relationship between presence and therapeutic efficacy in clinical participants. This is important; because immersive photography shows some advantages over VR, it offers more versatility and can be more economical. With immersive photographs it is possible to create as many environments as the therapist desires on demand with a high level of realism at a very low cost.

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