PRESENCE FOR VR EXPOSURE THERAPY THROUGH 3D ARCHITECTURAL VISUALIZATION

Ervin Sabadi
Willem-Paul Brinkman
Charles A.P.G. van der Mast
Delft University of Technology
Mekelweg 4, 2628 CD Delft
The Netherlands
Email: w.p.brinkman@tudelft.nl

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ABSTRACT

This paper reports on the effect of 3D architectural visualization in VR and its possible effect on the sense of presence. The problem definition was tested by use of a between subjects design. Two groups were randomly formed. One group evaluated the 3D visualized virtual environment, and the other the 2D visualized virtual environment. Afterwards the Igroup Presence Questionnaire was used to evaluate the sense of presence. This questionnaire covers three subscales (spatial presence, involvement, and experienced realism) and one additional general item ("sense of being there") not belonging to a subscale.
Two out of three subscales showed a significant improvement of the 3D visualized virtual environment. Involvement and the general item showed no significant difference. It is evident that the 3D architectural visualization provides us with a promising perceptual component for reaching a higher sense of presence for VR exposure therapy.

INTRODUCTION

The motivation for the work presented in this paper should be seen with the context of Virtual Reality Exposure Therapy (VRET). VRET is an instance of behavioral treatment devised on Virtual Reality (VR) technology. VRET has proven its efficacy in treating acrophobia (fear of heights), arachnophobia (fear of spiders), and fear of flying (Krijn et al. 2004). It has also shown promise for the future in treating other phobias like claustrophobia, fear of driving, fear of public speaking, posttraumatic stress disorder (PTSD), and agoraphobia (Powers&Emmelkamp 2008). VR is used to create immersive virtual environments with the aim to expose patients with phobias to controllable levels of anxiety. The patients have to withstand feared situations until their feeling of fear subsides to a certain level before they are directed to more challenging situations. The project "VR and phobias" has been started in 1999 in order to develop a VRET system for treating several phobias (Van der Mast 2006). In an effort to find out more about what causes people to experience the sense of presence (SoP) in VR, a study was started on basis of agoraphobia. Unlike most other phobias, a high avoidance level of feared situations may seriously damage someone's ability to work, to travel, or to even carry out the simplest daily routines. Robillard et al. (2003) indicate a synergistic relationship between presence and anxiety. Brinkman et al. (2008) report a search for parameters evoking presence for social phobia therapy.

Most VR research on the SoP is done by exposing participants to virtual environments. Many of these environments, if not all, are comprised of 2D and/or 3D elements. Even though this is the case, little attention has been paid to differences between the architectual building blocks in the virtual environments as a source for eliciting a SoP. This study focuses on researching 3D visualization in VR and its possible effect on the SoP. Being one of the largest historic market squares of Europe, the Delft market square was chosen for the project "VR and phobias" in researching VRET in respect to agoraphobia.

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THEORETICAL BACKGROUND

Agoraphobia

People with agoraphobia have feeling anxiety about being in places or situations from which escape might be difficult (or embarrassing) or in which help may not be available in the event of having an unexpected or situationally predisposed panic attack or panic-like symptoms. Two factors are essential with agoraphobia: *anticipatory anxiety* and *avoidance* of situations that cause anxiety. Anticipatory anxiety is the anxiety experienced by merely thinking about a possible attack, which might occur when starting some activity. It can be severe and even appear hours before the dreaded activity. Avoidance is a behavior which is caused by trying to avoid certain situations or activities, because of the fear of a panic attack. Common themes that accompany agoraphobia are:

- Distance from home
- Traveling alone
- Crowds
- Confinement
- Open spaces

- Social situations

A few example situations to put these themes in a better perspective are as follows:

- Standing in a cue
- Crowded shops
- Empty streets or markets
- Cinemas, theatres
- Traveling by car, train or airplane
- Being in an elevator

Presence

According to literature a defining component of VR systems in general is the feeling “sense of presence” (SoP) (Hodges et al. 1994). In relation to VR the concept of presence is best characterized by transportation; people immersed in VR are thought to feel present in the VE when they have the feeling of ‘being there’.
Much research has already been done on the subject of SoP and several researchers (Lombard&Ditton 1997, Witmer&Singer 1998, Slater&Usoh 1993, Sheridan 1992, Steuer 1992) have even composed categorizations of factors that contribute to that feeling.

The tools for measuring the SoP consist of objective measures and subjective measures. Objective measures come in two varieties: behavioral and physiological measures. Behavioral measures are based on behavior a person shows while immersed in a VE (Sheridan 1996, O’Brien at al. 1998). Physiological measures are directed at measuring presence through physiological changes like heart rate, skin temperature and skin conductance (Sheridan 1996). Subjective measures are used most frequently in researching presence. This is done through use of questionnaires. People immersed in a VE are probed with questions related to the projected environment in order to get a better understanding of the concept of presence.

METHODS AND MATERIALS

The idea was to develop two environments that resemble the market square in Delft. One environment would consist of 2D surroundings placed in such a way that they emit the illusion of a 3D setting. The other environment would consist of actual 3D surroundings, built to resemble the real world in a higher degree.
Researching the effect of 3D visualization on the SoP means introducing architecture into the realm of VR. In daily life architecture focuses on design and construction as a means of exhibiting a certain visual experience. Aside from the prominent visual aspect, architecture can also be experienced through our aural, olfactory and tactile senses. As Delft market square was chosen as candidate for this project, this meant recreating the historic market square up to a high level of realism. Using display optics (e.g. a HMD) we create depth perception to our brain by showing our eyes stereoscopic 3D imagery of computer generated visual data.
An experiment with test subjects immersed into the two different virtual environments was held in order to find out if there is a difference in the SoP which can be elicited by the fundamental build-up of the virtual environments.

Requirements analysis

Factors that contribute to a feeling of SoP in respect to 3D visualization in VR are (Lombard&Ditton 1997, Witmer&Singer 1998, Slater&Usoh 1993, Sheridan 1992, Steuer 1992):

- High quality
- Consistency
- Sensory factors
- Distraction factors
- Realism factors
- Vividness

Reference material

In order to start developing the virtual environments of Delft market square, reference materials were necessary. A visit to the market square itself was made. Using a Canon EOS 400D digital SLR camera with standard lens to snap pictures of the market square ended up in an inventory exceeding 200 photographs. The photographs depicted buildings, containers, lampposts, benches, chairs, tables, pillars, and more. All these objects needed to be photographed from different angles as much as possible, because 3D modeling requires it.

Design process

The 3D modeling software package Maya (v7.0.3) from Autodesk was used to model the required objects for the market square in Delft. The photographs formed the basis of each object. Two main categories can be distinguished in the way the objects needed to be modeled. One category consisted of modeling buildings and the remaining category consisted of modeling all other objects. The difference between these two categories lies in the way the original photographs were used. For the first category the
photographs were actually integrated into the final models of the objects, whereas for the second category the photographs were only used as an orientation aid during modeling.

Figure 1: Photograph with perspective

The out-of-camera pictures needed some adjustments before they could be used. The first step in modeling the buildings was to remove the visible perspective (figure 1).

After this the pictures were imported into Maya (and projected onto a polygon plane) where additional adjustments could be made.

The next step in the process was to cut out all the parts of the photograph that were not necessary. This way the contours of the final 3D model already started to get visible. After that, extra contours needed to be drawn onto the textured polygon plane. This was done around windows, doors, façades, and other components that are subject to visual depth. This can be seen in figure 2.

Figure 2: Building getting contours

Depth was applied onto the surface of the polygon plane on places where contours were drawn earlier in the process (e.g. around windows, doors, façades). This is clearly visible in figure 3.

Figure 3: Depth applied, left: polygon planes, middle: textures added, right: light source added.

The most left representation in figure 3 shows the look of the actual polygon plane without textures applied to it. From the sideway it is clearly visible that depth is present. The middle representation shows the same polygon plane, but now textured with the front view of the building that was being modeled. The depth information is now visible on the textured polygon plane. The most right representation shows the same polygon plane as the middle one, but now with a light source added to the scene.

After the front views of the buildings were modeled, the sides needed to be done as well. The back of the buildings consisted of a mirrored front view. Additional adjustments needed to be made to the roofs, as they needed to be in an angle with the front view. Figure 4 (right side) shows the final result.
After the buildings all the other small objects needed to be modeled as well.

So far the development of the 3D visualized virtual environment. For the 2D virtual environment the same photographs were used for consistency reasons. A 2D building would look like the building depicted in figure 2. The difference with the 3D version of the building would be the lack of depth. Figure 4 (left side) shows a view of the 2D visualized virtual environment.

The view of Delft market square formed the basis for the arrangements of the virtual environments which would be used for the experiment. The market square consisted of a relatively large square surrounded by numerous buildings. As far as the buildings were concerned, an attempt was made to place them in the same consecutive order, resembling the real market square as much as possible. After the Delft market square was modeled in Maya, it needed to be imported in Vizard. Vizard (v3.10.0059) was used to implement interactive navigation in the modeled virtual market square using a Head Mounted Display (HMD).

Figure 4: Final result of the market, left are the 2D models, right the 3D models. For the participants left and right are either 2D or 3D. This picture is only for comparison.

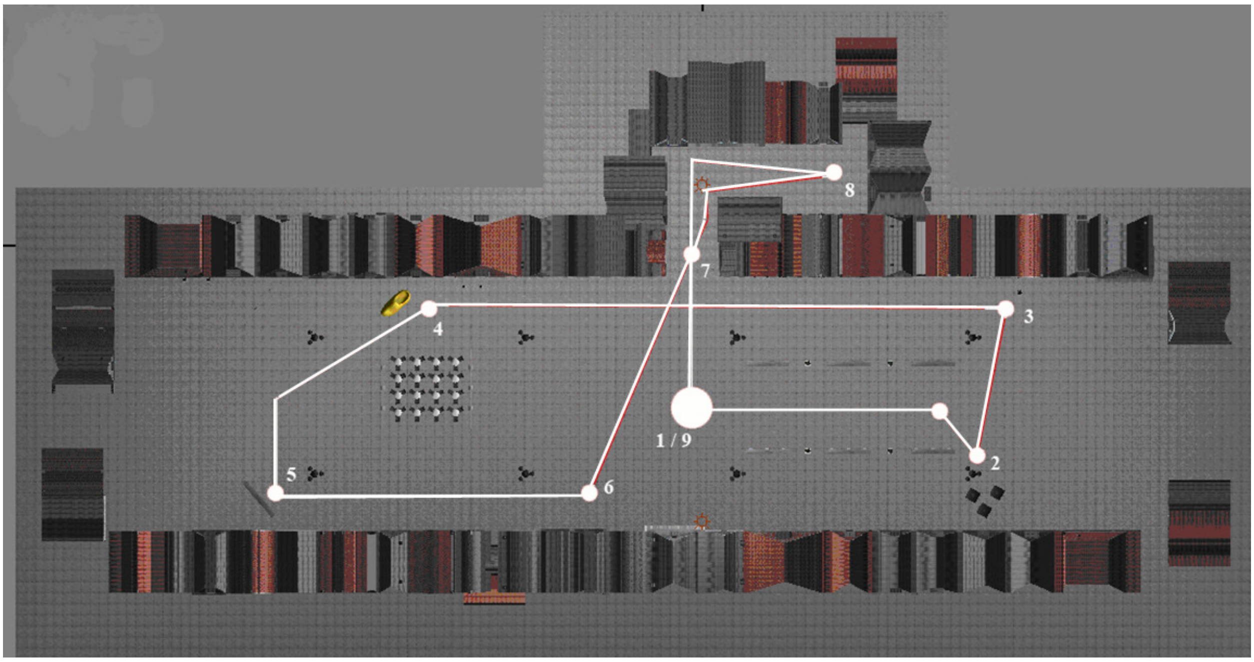

Figure 5: The path to walk.over positions 1-9

THE EXPERIMENT

Experiment set-up

An experiment was designed to test if the hypothesis was supported that the 3D architectural visualization in VR would provide a higher sense of presence in comparison to a 2D version of the same virtual environment. The experiment was run on a system with Microsoft Windows XP (SP3) installed on it. The porting from Maya to Vizard was done through a conversion program PolyTrans (v4.1.2) by Okino. The hardware on which the experiment was run consisted of a Dell Optiplex 755 with a Intel Core 2 Duo E6750 processor, 2048 MB of memory, and a NVIDIA Quadro FX 1700 graphics card. The HMD eMagin Z800 3Dvisor was used for viewing the developed virtual Delft market squares. In the experiment the participants were able to look around freely as the used HMD had a built-in 3 DoF (Degrees of Freedom) tracker. Because the tracker did not provide sensory information for movements, the navigation was controlled by the leader of the experiment.

The 20 participants were all students from Delft University of Technology. Two groups of 10 participants were randomly chosen. One group evaluated the 3D visualized virtual environment, while the other group evaluated the 2D visualized virtual environment. The average age of the group that tested the 3D VE was 24.1 year, whereas the average age for the group that tested the 2D virtual environment was 23.4 year. All the participants were male. The experiment lasted approximately 8.5 minutes, after which the participants were given the opportunity to assess their virtual environment trial with a questionnaire. The experiment had setup *between-subjects*.

The participants were informed about what was going to happen. They used the HMD to view a virtual environment, after which they would need to assess it by filling in a specific questionnaire to ascertain their SoP. They would be guided automatically between stopping points while they were immersed in the virtual environment, so that they would walk a specific path. The paths that were taken by the participants are depicted in figure 5 by lines following 1,2,3,4,5,6,7,8 and 9.

The numbered dots represent the moments in which the participants were given the opportunity to look around, and are numbered according to the direction taken. There are a few reasons why those points were chosen. First of all when participants entered the virtual environments, they would start at the center of the market square. This way both virtual environments (2D and 3D) got the opportunity to provide maximum depth information (especially the 2D virtual environment provides maximum depth information when a participant is right-angled towards the buildings). A few stops were made around objects, as extra visual depth information should be available at those places. This would provide both modeled virtual environments with the same kind of chance of acquiring a feeling of being there. Two trajectories were next to the buildings, in order for the participants to pick up the details brought on to the various buildings available in the 3D virtual environment, but missing in the 2D virtual environment. Hopefully this would trigger a difference between the two virtual environments in respect to a SoP. At point six in figure 5 a diagonal path was chosen directed towards the alley available in both virtual environments. The diagonal approach should favor both virtual environments with some points on depth information (even though the 2D virtual environment did not have 3D buildings, the HMD would provide a stereoscopic (depth) view of the alley), although it was expected that the 3D would reach higher sense of presence. Right at the beginning of the alley a stop was organized. The participants were given a chance to look around here and look at the buildings from close by. The 3D virtual environment should have an extra element of realism here, because of the 3D aspects of the buildings from nearby. After this the path continued into the alley, where it was the first time the participants were totally enclosed by buildings. The last trajectory was to walk out of the alley towards the starting point. This trajectory was chosen because of the changing view while leaving a narrow alley. It should give a good sense of presence in the virtual environments.

A total of eight paths had been introduced for the participants to take, and nine positions in which they would be left stand still in order for them to get a feel of their surroundings. At the stopping positions (including the starting position) the participants would get 30 seconds to look around freely before moving on to the next one. In total they would spend 235 seconds ‘walking’ (in which they would also be able to look around), and 270 seconds ‘looking’ (while stationary). The timings of each path the participants were taken, are documented in table 1. As a total, the participants were immersed into a virtual environment for approximately 8.5 minutes.

Table 1: Timing of the paths.

1.	*Path 1*	*2*: 30 s
2.	*Path 2*	*3*: 15 s
3.	*Path 3*	*4*: 50 s
4.	*Path 4*	*5*: 30 s
5.	*Path 5*	*6*: 25 s
6.	*Path 6*	*7*: 30 s
7.	*Path 7*	*8*: 20 s
8.	*Path 8*	*9*: 35 s

The questionnaire used to evaluate the SoP of the participants in the two different virtual environments, is the Igroup Presence Questionnaire (IPQ). The IPQ consists of 14 items, covering three subscales (spatial presence, involvement, and experienced realism) and one additional general item (“sense of being there”) not belonging to a subscale (IPQ, 2008).

RESULTS

The IPQ is based on a 7-point Likert scale itemts. This means that the answers can range from -3 (e.g. fully disagree) to +3 (e.g. fully agree), whereas position 0 portraits the meaning of neutrality towards the given situation. In order to make certain that the three subscales were consistent for this type of experiment, the Cronbach’s alpha was determined. For spatial presence $\alpha = 0.83$, for involvement $\alpha = 0.64$, and for experienced realism $\alpha = 0.80$.
To present the data in a way that distortion factors are excluded as much as possible the Likert scales were reduced to an ordinal level. All the responses were combined into three categories (negative/ neutral/positive). This means that the Likert scales

were relabeled as follows: [-3, -1] as negative, ⟨-1, 1⟩ as neutral, and [1, 3] as positive towards a SoP.
Examing the graph two IPQ subscales (*spatial presence* and *experienced realism*) showed a clear difference for VR (2D or 3D) in eliciting a SoP. Concerning *spatial presence* it is visible that the large majority of the participants stated that the 2D visualized virtual environments had a neutral effect on the SoP, whereas the participants who were immersed in the 3D visualized VE stated more often a positive effect on the same matter. The same applies for *experienced realism*, where the 3D visualized virtual environments shows better results as well. The reactions from the participants who were immersed in the 2D visualized virtual environments can mostly be found in the negative/neutral area, whereas the 3D visualized VE shows overwhelming responses in the neutral area. The results are presented in Figues 6 and 7.

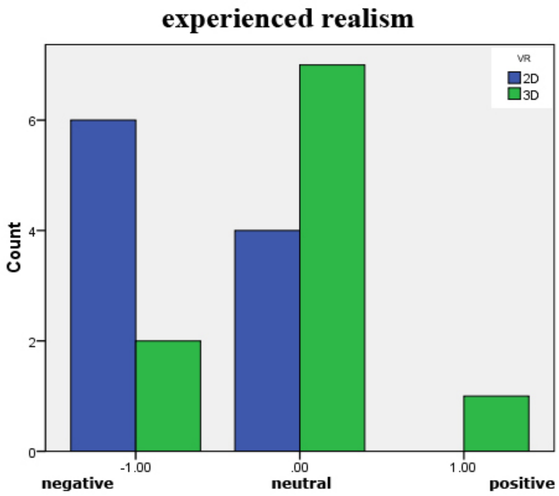

Figure 6: Experienced realism

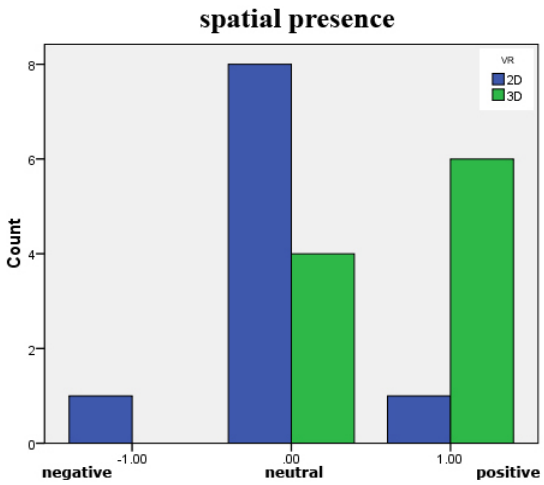

Figure 7: Spatial presence

Mann-Whitney U tests confirm these differences as can be seen in Table 2.

Table 2: Results of Mann-Whitney U

Measure	*p*	*U*	*Z*
Spatial presence	0.018	23.0	-2.37
Involvement	0.264	37.5	-1.12
Experienced realism	0.058	28.0	-1,90
‘Being there’	0.166	34.5	-1.39

Subscale *experienced realism* reached a value close to an α level of 0.05, that we could practically tag it as significant. Moreover, with a p = 0.018, we were able to add subscale *spatial presence* on the list of significance. This means that out of three available subscales we were able to find two of them showing significant differences between the 2D and 3D visualized VEs.

CONCLUSIONS AND RECOMMENDATIONS

Two out of three subscales showed a significant improvement of the 3D visualized virtual environment. One subscale and the general item showed no significant difference. Having found significant differences between the 2D and 3D visualized virtual environment is quite remarkable considering the small test group used in the experiment. It is evident that the 3D architectural visualization provides us with a promising perceptual component for reaching a higher sense of presence. It would be interesting to know what would happen with a larger test group.

A way to emphasize architecture in a three dimensional form in virtual reality could be done by using active lighting. Inserting active lighting in virtual reality would make it possible to introduce shadows. For virtual reality systems optics are used to fool the brain by showing our eyes depth perception. In our experiment architecture was used to actually introduce real depth in virtual reality, which showed promising results. By emphasizing the architectural factor in virtual reality through use of shadows, we may be able to further enhance the sense of presence. Vizard, the interactive real-time 3D program which was used for our experiment, does not support active shadowing through the introduction of lights. But perhaps it will be available in a future update of the program.

The people who participated in the experiment used in this research were all male (19 to 34 years) and technically educated. It is conceivable that a different composition of the participants and different age groups may result in different findings. We can expect that in the future patients who suffer phobia have a lot of experience with computer games and other high quality 3D worlds. And probably more 3D-realism might be required to evoke presence for them.

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