Reaching a higher sense of presence in VR through 3D architectural visualization

Delft University of Technology

Media and Knowledge Engineering
Master of Science Degree Program

Unit Human-Computer Interaction

Supervised by
Dr. ir. C.A.P.G. van der Mast
&
Dr. ir. W.P. Brinkman

23 October 2008

Ervin Sabadi
9724172

TUDelft

Reaching a higher sense of presence in VR through 3D architectural visualization

Ervin Sabadi (9724172)

Delft, 23 October 2008

Supervisors:
Dr. ir. C.A.P.G. van der Mast
Dr. ir. W.P. Brinkman

Graduation committee:
Dr. ir. C.A.P.G. van der Mast
Prof. dr. M.A. Neerincx
Dr. ir. W.P. Brinkman
Drs. P.R. van Nieuwenhuizen

Abstract

This thesis focused on researching 3D visualization in VR and its possible effect on the sense of presence. Being one of the largest historic market squares of Europe, the Delft market square was chosen as the most suitable candidate for the project "VR and phobias" in researching Virtual Reality Exposure Therapy in respect to agoraphobia. Two virtual environments resembling the market square in Delft were developed. One virtual environment consisted of 2D surroundings placed in such a way that they emitted the illusion of a 3D setting. The other virtual environment consisted of actual 3D surroundings, built to resemble the real world in a higher degree.

The stated problem definition was as follows:

"Can 3D (compared to 2D) architectural visualization in VR provide us with a perceptual component in reaching a higher sense of presence?"

This problem definition was tested by use of an experiment, which was held among students. Two groups were randomly formed and each group consisted of 10 participants. One group evaluated the 3D visualized virtual environment, while the other group evaluated the 2D visualized virtual environment. 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 Igroup Presence Questionnaire was used to evaluate the sense of presence of the participants in two different virtual environments. The Igroup Presence Questionnaire covers 14 items on basis of three subscales (spatial presence, involvement, and experienced realism) and one additional general item ("sense of being there") not belonging to a subscale.

Collecting the outcomes of the questionnaires from all participants provided us with an answer on the stated problem definition on virtual visualization and the feeling of presence. 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.

Table of contents

1. Introduction

Virtual Reality Exposure Therapy (VRET) is the outcome of cooperation between different disciplines, such as psychiatry, clinical psychology, psychotherapy, computer science, graphics design, Human-Computer Interaction (HCI), and engineering. Essentially VRET is a tool for 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. 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. VR is used to create immersive Virtual Environments (VEs) with the aim to expose patients with phobias to 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. With all the promises VRET holds, it has become a popular research item. In 1999 collaboration between several universities on project “VR and phobias” was started. Delft University of Technology is participating in this project in close cooperation with the University of Amsterdam (faculty of psychology). Each has its own responsibilities in relation to this project; Delft University of Technology takes care of the technical aspects of VR and the interaction between humans and computers, whereas the University of Amsterdam takes on VRET and the psychological aspects of VR. Together they have researched and developed a VRET system for treating several phobias. Positive outcomes of their studies have led to the introduction of their VRET system in several clinics.

1.1 Research goal

Although agoraphobia is commonly known as fear of open places, its meaning runs much deeper. When it remains untreated it may have serious consequences with regard to a person’s life; the worst case scenario would be for a person to become completely isolated from the rest of society. VRET can be a possible solution to agoraphobia. VRET systems are still in their infancy and aside from a few systems commercially available, most VRET developments happen in and around laboratories. A goal behind all this is to get the VRET systems out of the laboratories and into clinics. Before this becomes reality a lot of research is necessary, because even though VRET has proven its efficacy and has shown much promise in treating phobias, the exact underlying components to its success (or failure) are still unclear to this day. Together these components form the ‘DNA’ for an unambiguous successful application of VRET, and they need to be unraveled. According to literature a defining component of VR systems in general is the “sense of presence” (SoP).

People always know that an experience in for example VR is mediated, and to this date can distinguish between mediated and direct stimuli as technology has not exceeded the threshold where the difference between mediated and non-mediated stimuli becomes fuzzy. Though at some level the illusion of non-mediation can be sensed, and the people immersed in VR can actually have the sense of being present in the virtual setting. For VRET it is not necessary to achieve a 100% lookalike with the real world, but what aspects of the real world do we need to take into account in order to achieve a higher or a more constant SoP?

This thesis will focus 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 as the most suitable candidate for the project “VR and phobias” in researching VRET in respect to agoraphobia. The idea is to develop two VEs that resemble the market square in Delft. One VE will consist of 2D surroundings placed in such a way that they emit the illusion of a 3D setting. The other VE will consist of actual 3D surroundings, built to resemble the real world in a higher degree. An experiment with test subjects immersed into the two different VEs will be 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 VEs.

The problem definition which will be tackled is as follows:

“Can 3D (compared to 2D) architectural visualization in VR provide us with a perceptual component in reaching a higher sense of presence?”

1.2 Thesis outline

The build-up of this thesis assignment is as follows. The first chapter has started on the previous page with a general introduction. Chapter two will give a short summary of the whole design process concerning this thesis. Chapter three will discuss anxiety disorders and in specific agoraphobia, whereas chapter four will move on to VR and VRET. Chapter five will pay attention to sense of presence, which is of great importance for VRET. After that, chapter six will address the introduction of architecture into the realm of VR, and give explanation on how the virtual elements came to life. The results of the experiment will be presented in chapter seven, which will be followed by the last chapter discussion & conclusion.

2. Research method

The fundamental emphasis in this research was to test 3D visualization in VR as a possible influence on the sense of presence (SoP)[1]. The VRET system had to use the Delft market square, one of the largest historic market squares of Europe[2], as a starting point in the design process. After the design process an experiment was to be held in order to test the problem definition given in the previous chapter.

2.1 Research

The research phase consisted of a literature study in which a broad search on all kinds of subjects related to VRET and agoraphobia was performed. Information from various sources was used, including books, articles, Internet, medical –and technological databases, and so on. Special attention was paid to a previously started research[3] in which the Delft market square was implemented as a prototype VE. That research focused on efficacy parameters in respect to agoraphobia.

This thesis will focus on researching 3D visualization in VR and its possible effect on the SoP. A reason to do this is that aside from all the technical issues and the efficacy measurements, VRET systems need to look good if they ever want to become an accepted treatment tool for phobias. The cause for this lies in home entertainment and games, as they have become integrated in many people's lifestyles. One could even speak of graphical indoctrination versus successful commercialization of VRET systems. Many of the game engines have advanced far in mimicking realism; virtual surroundings with shadowing, avatars with realistic gestures and other body movements, realistic simulation of hair and clothes, and facial expressions. These factors may prove to be helpful in increasing the SoP, and thus increasing the efficacy of VRET treatments.

2.2 Development

VEs are unique when it comes to development techniques. Research on current design practice for VEs characterizes their development as informal and is based on an iterative approach.[4] Table 2.1 enumerates the steps generally taken in the development phase.

Table 2.1

Steps generally taken in VE development[4]
1) Requirements specification
2) Gathering of reference materials from real world models
3) Structuring of graphical models, sometimes dividing it between designers
4) Building objects and positioning them in the VE
5) Enhancing the environment with texture, lighting, sound and interaction, and optimizing the environment

These steps were followed in the development of the VEs of Delft market square. After the VEs were finished, it was necessary to import them into an external interactive 3D graphical program. This step was necessary for the next phase; the evaluation phase.

2.3 Evaluation

In order to evaluate the problem definition a subjective measurement was used. An almost exclusive way of measuring presence is through use of subjective questionnaires. They lend themselves best for rich feedback required for evaluating a phenomenon like presence.[5] For this thesis the IPQ (Igroup Presence Questionnaire) was chosen as the best candidate for researching 3D visualization in VR as a means of affecting the SoP in a positive way.[6]

3. Anxiety disorders

Anxiety is a biological mechanism that provides us with the ability to adequately respond to dangerous situations. The state of mind is accompanied by physiological changes in order to reach the necessary response, including increased heart rate, blood pressure, respiration, and muscle tension.[7] This human emotion can literally be life saving. When the anxiety becomes disproportionate to the severity of the threat, continues after the threat has subsided, or occurs in the absence of any external threat, it becomes a disorder.[8] The impact of this disorder on a human life can be of such magnitude that it compromises the quality of life and social functioning.

3.1 Panic disorder

Panic disorder is one of the most common and important anxiety disorders in the European population.[9] The essential features of panic disorder are enumerated in table 3.1. Cognitive models[10, 11] hypothesize that people who suffer from panic disorder falsely interpret physiological sensations as a sign of serious illness (e.g. heart attack). This indicates that it is the interpretation accredited to the physiological sensations that causes the panic attacks, and not the physiological sensations themselves.

Table 3.1

DSM-IV-TR: Diagnostic criteria for panic disorder[12]
1) Recurrent unexpected panic attacks
2) At least one of the attacks has been followed by 1 month (or more) of one (or more) of the following:
a) Persistent concern about having additional attacks
b) Worry about the implications of the attack or its consequences (e.g., losing control, having a heart attack, “going crazy”)
c) A significant change in behavior related to the attacks

Diagnostic criteria of a panic attack can be found in table 3.2. DSM-IV acknowledges a panic attack when at least four of these symptoms are diagnosed. It is called a minor attack in case less than four of the symptoms are diagnosed. The frequency and severity of a panic attack can vary widely.

Table 3.2

DSM-IV: Diagnostic criteria of a panic attack (not a codable disorder)[13]
A discrete period of intense fear or discomfort, in which four (or more) of the following symptoms developed abruptly and reached a peak within 10 minutes:
1) Palpitations, pounding heart or accelerated heart rate (tachycardia)
2) Chest pain or discomfort
3) Sensations of shortness of breath (dyspnoea) or smothering
4) Sensation of choking
5) Feeling dizzy, unsteady, or light headed
6) Depersonalization (being detached from oneself), derealisation (feelings of unreality)
7) Paraesthesias (numbing or tingling sensations)
8) Hot flashes or chills
9) Trembling or shaking
10) Sweating
11) Nausea or abdominal distress
12) Fear of dying
13) Fear of loosing control or going crazy

When panic attacks remain untreated, they may have serious consequences. There is always the immediate danger of panic attacks leading to the development of a phobia. Approximately one out of three people with panic disorder develops a phobic fear in the disabling form of agoraphobia.[13, 14]

3.2 Agoraphobia

Agoraphobia was first described in 1871 by a German psychiatrist and neurologist Karl Friedrich Otto Westphal[15] and is commonly known as fear of open places. This misconception can be found in its derivation from Greek words (agora and phobos), which literally means “fear of the marketplace”.

Two factors are present 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. Agoraphobia comes in two different varieties: with panic disorder, and without panic disorder.

3.2.1 Agoraphobia with panic disorder

The classification of agoraphobia in accordance with the American system DSM-IV-TR is given in table 3.3.

Table 3.3

DSM-IV-TR[12]: Agoraphobia (not a codable disorder)
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. Agoraphobic fears typically involve characteristic clusters of situations that include being outside the home alone; being in a crowd of standing in a line; being on a bridge; and traveling in a bus, train, or automobile… The situations are avoided (e.g., travel restricted) or else are endured with marked distress or with anxiety about having a panic attack or panic-like symptoms, or require the presence of a companion. …

3.2.2 Agoraphobia without panic disorder

Another form in which agoraphobia can be diagnosed is agoraphobia without panic disorder. It represents a relatively small part in comparison to agoraphobia with panic disorder. Both forms of agoraphobia share the same essential features. The difference can be found in the aspect of fear. In the case of agoraphobia with panic disorder the fear focuses on full panic attacks, whereas the fear in agoraphobia without panic disorder focuses on paniclike symptoms or limited attacks which can render a person incapacitated or put them in an embarrassing situation.

3.2.3 Agoraphobia: signs and symptoms

Even with all the definitions of agoraphobia at hand, it is still difficult for doctors to diagnose the disorder. A doctor has to carefully examine a patient and look for symptoms that can give an insight into the patient’s health situation. Taking the patient’s description of the symptoms into consideration, the doctor has to exclude any or all other mental and physical disorders or diseases, in order to diagnose agoraphobia. As agoraphobia can manifest itself in different severity levels, this can form an extra difficulty in the diagnosis. The discomfort a patient may experience from agoraphobia can range from mild uneasiness (with none to little avoidance), to severe distress (with marked avoidance). Some people that suffer from agoraphobia are able to expose themselves to the situations they fear, but they will do it reluctantly and with a lot of dread. It is easier for these people to face their fears with a companion, be it a person or an object (e.g. a walking stick). In the more severe cases of agoraphobia 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. The worst case agoraphobia scenario can render a person totally incapacitated, where leaving the house or staying home alone becomes an impossible task.

Common feared and avoided situations by agoraphobics can be found in table 3.4. The characteristics of the summed-up situations in table 3.4 make it clear why agoraphobia can have a disabling grasp on someone's life.

Table 3.4

Situations feared and avoided by agoraphobics
Common themes: o Distance from home o Traveling alone o Crowds o Confinement o Open spaces o Social situations Examples: o Public transport o Standing in a cue o Crowded shops o Empty streets o School visits o Cinemas, theatres o Traveling by car, train or airplane o Being on a bridge o Being in an elevator

Agoraphobia can manifest itself in different ways, psychologically and physically. The physical symptoms of agoraphobia are similar to those of a panic attack as described in table 3.2. Extra symptoms that can arise are a blurred vision, buzzing in the ear, a dry mouth, and backache. Examples of psychological manifestation of agoraphobia can be various, e.g. feeling depressed, feeling of light-headedness, low self-esteem, frustration, state of confusion, anxiety and panic attacks, or even drug –or alcohol abuse. From this it is clear that the disorder can influence the state of mind a person is in at a specific time (during a feared situation, or in expectation of the feared situation).

4. Virtual Reality

The term Virtual Reality (VR) was popularized in the early 1980s by Jaron Lanier[16], though it was Ivan E. Sutherland (1968) who is usually considered to be the founder of the technology. There is not one exclusive answer to what VR means, though many of the existing definitions show similarities. Table 4.1 gives a few examples of definitions on the term VR.

Table 4.1

Defining Virtual Reality
A computer simulation of a real or imaginary system that enables a user to perform operations on the simulated system and shows the effects in real time.[17]
A hypothetical three-dimensional visual world created by a computer; user wears special goggles and fiber optic gloves etc., and can enter and move about in this world and interact with objects as if inside it.[18]
A computer simulation of a real or imaginary world or scenario, in which a user may interact with simulated objects or living things in real time. More sophisticated virtual reality systems place sensors on the user's body to sense movements that are then interpreted by the system as movements in the simulated world; binocular goggles are sometimes used to simulate the appearance of objects in three dimensions.[19]
The creation of images and tactile sensations by means of a computer, producing the illusion of reality. Images are often projected onto special goggles to strengthen the illusion.[20]

There are two main categories of VR systems, namely immersive and non-immersive.

4.1 Immersive Virtual Reality

The main goal of immersive VR is to immerse a person into a VE in such a way that the person really feels present in the projected VE and actually perceives it as reality, a Virtual Reality. A computer generates a VE which is presented to the person through means like stereoscopic imagery or projection systems. An example of stereoscopic imagery is the Head Mounted Display (HMD), which is a device (just as the name implies) mounted on the head with a small display optic in front of each eye. A tracker on the HMD keeps track of head movements, so that the right visual orientation is displayed through the display optics.
Cave Automatic Virtual Environment (CAVE) is an example of a projection system, which can be called a theatre-room. Only this is not a mere theatre-room as we know it: the surrounding walls, floor and ceiling are rear-projection screens. Special glasses need to be worn to allow for the 3-D graphics that are generated by CAVE to be seen. This way people can actually walk around 3-D objects or even see them flying.

4.2 Non-immersive Virtual Reality

Non-immersive VR is also known as Desktop-based VR. Animated interactive 3D graphics are presented on a desktop display in front of a person. This person does not need to wear special goggles like a HMD and no head tracking is applied with this kind of VR technology. Having to look directly at the desktop display has the lack of peripheral vision as a side-effect. A common criticism of Desktop-based VR is that because of this a user is less aware of the VR surroundings or their location in the VE, though there are those that counter that by suggesting that proper use of 3D and interactive animation can draw users into the virtual world just as well as immersive VR. Video games are a good example of Desktop-based VR, where immersion is likely to occur because of deep involvement. Though special goggles are not necessary, there are Desktop-based VR systems that use simple (colored) glasses (with specific software) in order to bring the 3D graphics to life on the 2D desktop display. Because of the development of 3D monitors people will actually see 3D soon, as this technology will let people see high resolution 3D images without the use of glasses or additional software. To be able to walk and look around in the virtual world, simple input devices like 3D pointing devices (a joystick, mouse or digitizer) or a keyboard are used.

4.3 Interfaces to Virtual Reality

We distinguish two main types of imagery interfaces which provide us with a way to see the VR world: stereoscopic –and projection interfaces. The most important example of stereoscopic interfaces is the Head Mounted Display (HMD). The most advanced projection interface is the Cave Automatic Virtual Environment (CAVE). These imagery interfaces will now be discussed.

4.3.1 Head-Mounted Display

A Head-Mounted Display is a device (just as the name implies) mounted on the head (figure 4.1). It has either one or two small display optics (LCDs or OLEDs for example) imbedded in the device, which are positioned in front of the eyes. The display optics show a stereoscopic 3D image of computer generated visual data, in order to create depth perception to our brain. This is achieved by providing the eyes of the viewer two different images, each with a different perspective of the same object. Built-in speakers (placed over the ears) complement the experience with matching VR environmental sound. For even more realism a head-tracking device can be mounted on the HMD. This way whenever a change in the viewer's head position –or orientation is registered, the correct image is displayed on the HMD optics.

Figure 4.1 Global Pl@yer by Siemens

4.3.2 Cave Automatic Virtual Environment

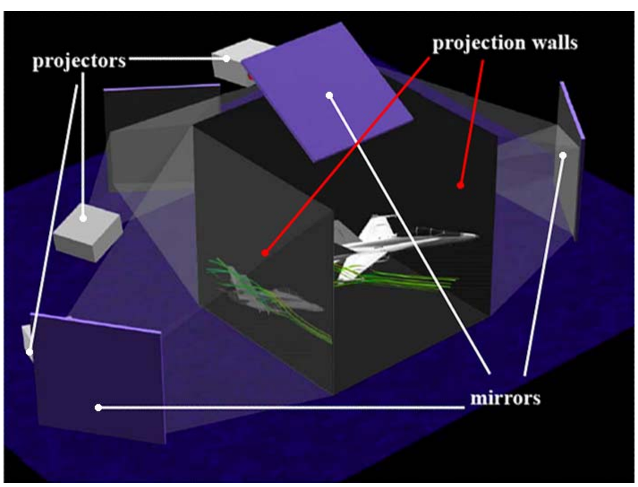

Figure 4.2 Representation of a CAVE system

The Cave Automatic Virtual Environment is a "theatre room" of approximately 3x3x3 (meters) and is designed to completely immerse people into the realm of VR (figure 4.2). The projection technology provides a high level of realism by using photo realistic images. CAVE systems do not require the observer(s) to wear cumbersome helmets in order to experience VR; all that's necessary are lightweight stereo glasses. Next to a surround VE, the CAVE systems complete the VR immersion with surround sound and tracking technology for producing the right perspective.

4.4 Interacting with Virtual Reality

Our senses provide us with vision, sound, taste, touch and smell, which are interpreted by our brain in order for us to be able to 'view' the world that surrounds us as a whole. Each of these sensory systems appear quite independent. Research on intermodal integration however suggests otherwise; the impression of sensory independence is "more illusory than real".[21] The same upholds for VEs; for our brain to be able to construct a spatial mental model of the VE, information from the visual, aural, haptic and other sensory channels must be integrated.[21, 22] We already possess the ability to create vision and sound of VEs and even though it does not come close to our own sight or hearing in respect to the real world, it has proven to be enough for treating phobias.[23] The senses touch, smell and taste have proven to be more challenging to integrate into VR. Of these three senses the touch will be highlighted and treated in the next paragraph.

4.4.1 Virtual touch

Tangibility, or in most cases of VR the lack of, has proven to be difficult to implement. To handle the area of touch in a good way, it has been broken down into two different areas: force feedback and tactile feedback.

4.4.1.1 Force feedback interaction

Force feedback can be conveyed in many ways onto the human body. To be able to touch objects in VR, haptic exoskeleton devices were developed. The development of exoskeleton devices was initially applied on only a few fingers. Soon the development moved to all the fingers, after that to the whole hand, the whole arm and as closure to the whole body. A full-body haptic exoskeleton suit is at this moment still in its infancy, but the future possibilities are very promising.[24] Figure 4.3 shows the haptic exoskeleton glove interface CyberGrasp from Immersion. CyberGrasp adds resistive force feedback to all fingers, making it possible for us to feel the size and shape of computer-generated 3D objects in VR. Haptic exoskeleton devices are getting more and more advanced, lightweight and easier to use (wear).

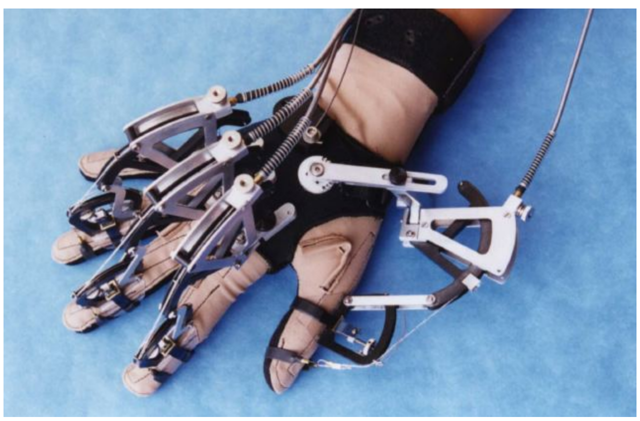

Figure 4.3 CyberGrasp from Immersion

4.4.1.2 Tactile feedback interaction

Tactile feedback is an even more concentrated form of feedback than force feedback is. Force feedback handles the perception of our surroundings in a VE, for example giving us feedback when we come in touch with an object. Tactile feedback handles the "feel" of virtual objects. In other words where force feedback stops tactile feedback picks up. In real life we take for granted that we are able to feel; all we need to do is reach out and touch. By touching we are able to extract specific information, information that we otherwise would not be able to obtain just by looking. Let's say we see a transparent glass vase on a table. We can see its form and color and even guess it is made of glass. But by touching we acquire even more information on the vase; we can feel if it is cold or warm, if it is smooth or coarse, if it is heavy or light, and so on. Of all these characteristics, the texture of an object is probably the hardest feature of tactile feedback to simulate. We use our hands the most in order to feel our surroundings, and that is why tactile feedback devices are mostly aimed at the hands.

Another possible form of tactile feedback is moving air (a breeze or wind). It is invisible and yet it provides us with an extra tactile feedback for our brains to construct a spatial mental model of our surroundings. Some research on this matter provides information that participants have the feeling that the breeze helps them feel more present in the VE.[25]

4.4.1.3 Brain-Computer interaction

Figure 4.4 Project Epoc

A relatively new interaction method is BCI, which stands for Brain-Computer Interface. BCI represents a direct communication channel to our brain by processing and translating brain activity into commands which are than wired through to a computer (figure 4.4). A headset placed on the head of the user measures electrical activity generated by neurons in our brain. The measuring technique used in this is called EEG (Electroencephalography). The results from the EEG are than used to create control signals which the computer than executes. Some of the research on the subject of BCI has been done at Delft University of Technology.[26] What makes this technology interesting is that the interaction itself does not depend on peripheral nerves and muscles of the human body. BCI is still in its infancy, though in the future it could be used for interacting with virtual objects in a VE. The technique would have to lean on visual feedback as the interacting would be done directly by our brain.

4.4.1.4 Kinesthesia

Human haptics is not a standalone function of the human body. For the human body to interact correctly with its surroundings, it needs to be complemented with extra information. This extra information comes in the form of kinesthesia (table 4.2).

Table 4.2

Defining Kinesthesia[27]
3) The sense that detects bodily position, weight, or movement of the muscles, tendons, and joints 4) The sensation of moving in space

Kinesthesia works as an automatic body feedback system providing somatosensory information to the brain from various internal and external body locations and head.[28] It is a key component to muscle memory and hand-eye-coordination. Muscle memory enables us to use our muscles in a fine and gross way; fine skills like brushing our teeth or using a pen to write, and gross skills like driving a car or golfing. Hand-eye-coordination is subdivided in fine –and gross motor coordination; fine motor coordination like small muscle movements of the fingers (manipulating small objects) supported by our vision, and gross motor coordination like walking, jumping and climbing. In simple terms it does not matter if we are either swinging a club or catching a ball, in order for us to actually hit or catch that ball, our brain already knows how our body is positioned internally and externally and how it needs to move (through training).

4.5 Virtual Reality Exposure Therapy

Virtual Reality Exposure Therapy (VRET) is the outcome of cooperation between different disciplines, such as psychiatry, clinical psychology, psychotherapy, computer science, graphics design, Human-Computer Interaction (HCI), and engineering.[29] Essentially VRET is an exposure therapy based on VR, where VR is used to create immersive VEs with the aim to expose patients with phobias to levels of anxiety. VRET has proven to be effective in treating acrophobia (fear of heights), arachnophobia (fear of spiders), and fear of flying.[30] VRET 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.[30] According to literature three conditions must be met in order for VRET to be effective.[31] The three necessary conditions are given in table 4.3.

Table 4.3

Necessary conditions for an effective VRET system[31]
Three conditions need to be met in order to create an effective VRET system: 1. *Sense of presence*: a person immersed in a VE needs to have the feeling of "being there" 2. *Provoke emotions*: a VE with the ability to elicit emotional responses (e.g. anxiety) from a person 3. *Generalization*: the subsidence (to extinction) of fear and other co-occurring cognitive changes need to have a generalized link with reality, so that what has been achieved in VR is also achieved in real life

VRET systems are still in their infancy and their introduction into society on a large scale is long in coming. Aside from a few systems commercially available on the market, most VRET developments happen in and around laboratories because of the available know-how. A goal behind all this is to get the VRET systems out of the laboratories and into clinics, where they can be used by therapists for treating patients with phobias. Advantages of VRET systems over traditional treatments are numerous. A couple of these advantages are given in table 4.4.

Table 4.4

VRET advantages over traditional treatments
1. *Control and safety*: the therapist has a high degree of control on emotional responses from the patient and is able to grade the feared situations easier, consequently having a high safety level for the patient.[32, 33] 2. *Privacy and confidentiality*: treatment takes place in the therapist's office shut off from the outside world and a possible curious public, providing the patient with privacy and confidentiality in a way in vivo exposure therapy is not able to.[32] 3. *Time and cost effectiveness*: the therapist has a large variety of VEs to his disposal as an alternative to in vivo exposure, saving the therapist money through a more effective use of time and no travel expenses.[32, 33, 34] 4. *Interoceptive exposure*: imaginary exposure is simply done in the therapist's consultation room, whereas VR can immerse a patient in various VEs providing a more natural setting in order to provoke bodily emotions.[32] 5. *Gradualness*: VR provides the possibility for a more gradual build-up of assignments, in sequence and in treatment.[33] 6. *Low threshold*: in vivo phobic exposures are sometimes too frightening for patients even under supervision of a therapist, whereas the thought of an immersive VE is less of a problem, providing the therapist with a treatment tool for certain (extreme) cases of phobia.[32] 7. *Variation and uniqueness*: every phobia case is different, giving rise to the need of flexibility within exposure therapy. VRET can fill this need because of its ability to create manifold VEs, each with an individual approach conformed to the uniqueness of each patient (e.g. scenarios for war veterans with PTSD).[33] 8. *Repetition*: exposure assignments can be performed as many times as needed (e.g. landing of an airplane).[33]

Advantages are mostly accompanied by disadvantages, though this is hardly the case with VRET. The only disadvantage of VRET that has been discovered to this date is simulation sickness. Simulation sickness arises when there is a discrepancy between the visually perceived movement and the vestibular system's sense of moment. In real life, when our head changes direction, the image of our surroundings on our retina changes correspondingly at the exact same time and rate as the vestibular system indicates movement of the head. However this is not the case for VRET systems because a specific amount of time is needed to process environmental changes in VR (due to a user's input) before a visual representation of the changes is shown to our eyes in the HMD. The resulting update lag subsequently causes simulation sickness, which is accompanied by symptoms like nausea, sweating, stomach awareness, increased or decreased salivation, dizziness, headache, and so on. Luckily most patients are not susceptible to simulation sickness, and when they are it can be prevented by taking breaks during VRET sessions.

Though not yet proven, there is some evidence that personality characteristics may affect the effectiveness of VRET.[35] Future studies should therefore investigate characteristics such as degree of absorption and hypnotizability in order to establish a successful VRET system.

5. Presence

According to literature a defining component of VR systems in general is the feeling "sense of presence" (SoP).[36] Because it is widely used in society, defining "presence" proves to be a difficult task. Numerous definitions can be found. Lombard and Ditton[37, 38] have managed to identify the most prominent ones used in literature (table 5.1).

Table 5.1

Defining Presence
Prominent usage of the word "Presence" in literature, by Lombard and Ditton[37, 38]: a) *Social richness*: the extent to which the medium is perceived as sociable, warm, sensitive, or personal when it is used to interact with other people b) *Realism*: the extent to which a medium can seem perceptual and/or socially realistic c) *Transportation*: the sensations of "you are there," "it is here," and/or "we are together" d) *Immersion*: the extent to which the senses are engaged by the mediated environment e) *Social actor within medium*: the extent to which the user responds socially to a representation of a person through a medium f) *Medium as social actor*: the extent to which the medium itself is perceived as a social actor (e.g., treating computers as social entities[39])

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'. When other people join the VR as well, the sense of being together is called co-presence or social presence. Following this line of thought behind 'being there', more than one type of presence can be thought of. Table 5.2 gives two different approaches for the subdivision of presence.

Table 5.2

Types of presence
Heeter[40] (1992) distinguishes the following types of presence: a) *Personal presence*: a measure of the extent to which the person feels like he or she is part of the virtual environment (VE) b) *Social presence*: refers to the extent to which other beings (living or synthetic) also exist in the VE c) *Environmental presence*: refers to the extent to which the environment itself acknowledges and reacts to the person in the VE Schloerb[41] (1995) distinguishes the following types of presence: a) *Subjective presence*: the likelihood that the person judges himself to be physically present in the remote or virtual environment b) *Objective presence*: the likelihood of successfully completing a task

A recent review of previous literature on presence by Kwan Min Lee takes an in-depth look at presence and the limitations of existing typologies.[42] Among the existing typologies are the ones given in table 5.2 by Heeter and Schloerb. Kwan Min Lee explains that there are two limitations in the existing typologies. The first limitation is that they explain the virtual physical experience always in connection with virtual self-experience, which is not applicable to a possible sense of presence created by low-tech media, i.e. television (television viewers may feel that the depicted virtual physical objects on a television are actual, without feeling any sense of transportation). The second limitation is that their classifications are not mutually exclusive (the given types of presence overlap each other). For example in the case of Heeter *environmental presence* is very likely to be a contributing factor for *personal presence* rather than a factor on its own (one will feel more present in the VE when the VE starts reacting to you). Schloerb's typology also has its limitations as it is illogical to talk about objective presence only when a task is completed successfully. Another serious limitation finds itself in the impossibility of objective telepresence. As a conclusion Kwan Min Lee redefines the definition of presence and its typology (table 5.3). In this he uses the same terms as in Biocca's[43] typology, although the explication of each type of presence is substantially different in order to deal with the limitations of the previous typologies.

Table 5.3

Redefining presence
Kwan Min Lee[42] redefines presence as "a psychological state in which virtual objects are experienced as actual objects in either sensory or nonsensory ways." And defines the following three types of presence: a) *Physical presence*: a psychological state in which virtual (para-authentic or artificial) physical objects are experienced as actual physical objects in either sensory or nonsensory ways b) *Social presence*: a psychological state in which virtual (para-authentic or artificial) social actors are experienced as actual social actors in either sensory or nonsensory ways c) *Self-presence*: a psychological state in which virtual (para-authentic or artificial) self/selves are experienced as the actual self in either sensory or nonsensory ways

5.1 Theories on presence

Several theories have been proposed in literature on the concept of presence in immersive VR. Schuemie[44] describes three theories: *presence as non-mediation*, *presence as focusing of attention*, and *presence as natural interaction*.

The theory of presence as non-mediation tells about the fact that people always know that an experience in for example VR is mediated, and to this date can distinguish between mediated and direct stimuli as technology hasn't exceeded the threshold where the difference between mediated and non-mediated stimuli becomes fuzzy. Though at some level, the illusion of non-mediation can be sensed (people respond to a mediated stimuli in VR as if it is non-mediated). Table 5.4 gives a more general explication of presence in order to define the above described theory.

Table 5.4

Presence as non-mediation[44] (Quote)
*Presence (a shortened version of the term "telepresence") is a psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through humanmade technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at *some level* and to *some degree,* her/his perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience.*

The theory of presence as focusing of attention is based on the belief that both involvement and immersion are necessary for the SoP. This belief is explained by the notion that focusing a person's attention will get the person more involved and consequently let him/her experience a higher SoP (table 5.5).
Table 5.5

Presence as focusing of attention[44, 45]
Relating presence to attention through attentional aspects: a) *Involvement*: a psychological state experienced as a consequence of focusing one's attention on a coherent set of stimuli or related activities and events b) *Immersion*: defined as a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with a VE

The theory of presence as natural interaction speaks of an environment which supports various actions that enables us to think oneself as existing ('being there') in that environment, heightening SoP. Basic concepts of this theory are given in table 5.6.

Table 5.6

Presence as natural interaction[44, 46, 47, 48]
Relating presence to natural interaction. Basic concepts of this theory are: a) *The environment offers situated affordances*: the term affordance was coined by Gibson[49] and is meant to describe the possibilities or opportunities that the environment offers for a particular organism b) *Perception-action coupling*: an organism perceives its environment primarily in terms of its affordances, making perception dependent on possible action c) *Tools become "ready-to-hand."*: using a tool eventually stops the user from possessing a stable representation of the tool.[50] The user is no longer aware of the tool itself but only of the usefulness the tool has in whatever task is performed.

5.2 Causes of presence

Researchers are trying to grasp the essence of presence, and given all the attention it is getting there might be some truth to it. But in order to research what role exactly SoP is playing in immersive VR, the factors that contribute to that feeling must be exposed. Much research has already been done on that subject and several researchers have even composed categorizations of these factors. Table 5.7 gives an enumeration of these factors from various researchers' point of view.[51]

Table 5.7

Categorizations of factors that contribute to a SoP
1. Slater and Usoh[52]: a) *High quality*, high resolution information b) *Consistency* across all displays c) *Interaction* with environment d) *Virtual body*, the representation of the user's body in the VE e) *Effect of action* should be *anticipated* 2. Witmer and Singer[45]: a) *Control factors*, the control the user has b) *Sensory factors*, the richness of the displayed information and consistency across displays c) *Distraction factors*, how much the user is distracted from the VE d) *Realism factors*, pictorial and social realism of the VE 3. Sheridan[53]: a) Extent of *sensory information* b) *Control* of relation of sensors to environment c) Ability to *modify physical environment* 4. Lombard and Ditton[37]: a) The *form* in which the information is presented b) The *content* of the information *c) User characteristics* 5. Steuer[54]: a) *Vividness* refers to the ability of a technology to produce a sensorial rich mediated environment b) *Interactivity* refers to the degree to which users of a medium can influence the form or content of the mediated environment c) *User characteristics* refers to the individual differences in users

The given categorizations show some similarities in some respects and none in others. For example Witmer and Singer categorize sensory factors as Sheridan does with sensory information. Slater and Usoh categorize interaction with the environment, where Witmer and Singer write about the control a user has, Sheridan writes about the ability to modify the physical environment, and Steuer writes about the interactivity with the mediated environment. Distraction factors of Witmer and Singer on the other hand are not voiced by the other researchers, and so on. Because of the level of difficulty in stating something as tough to grasp as SoP is, there is bound to be some overlap in categorizations of it.

Recent attempts at researching what causes presence are also being sought in the corner of emotions. It seems that SoP is closely related to emotions that a VE can provoke upon a subject and by being able to make a VE that can actually elicit emotional responses from a subject, makes it credible to consider emotions as an indicator for the degree of presence. A very interesting research on the matter of emotions in cooperation with VR has recently been announced (24 September 2007). The name of this research is “Trauma therapy: The nightmare machine”.[55] The basic idea behind this research is to develop a VR recreation of a traumatic event that reacts to a subject’s emotions in a “torture”-like way: a VR system that detects when a person is not scared enough and intensifies the VR traumatic event in order to scare you more. In order to determine a person’s emotional state, the system will rely on skin conductance –and temperature, electrocardiogram (ECG), breathing rate, and blood pressure. At this moment in time, research on the matter of emotions still needs further investigation.

5.3 Measuring presence

Starting with what we know about the SoP and how it can manifest itself, the next step in line is to try to measure it. In order to be able to do that ‘tools’ have to be developed. 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. By examining the behavior to mediated stimuli an objective measurement of presence could be achieved. Mediated stimuli can range from measuring reflex responses[56] like catching a ball or trying to avoid an object, to analyzing human-to-human interaction in multi-user VEs[57]. Physiological measures are directed at measuring presence through physiological changes like heart rate, skin temperature and skin conductance.[53]

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. The questions asked range from as much as one question to as many as need be. Simple questions like “what do you see?” or “do you feel present in the VE?” are asked. An advantage of questionnaires is that they not only measure subjective sensations experienced while being immersed in a VE, they can also give insight in physiological and behavioral responses of a person. These physiological and behavioral observations are of course not very reliable because of their subjective nature. In order to present reliable and validated questionnaires systematic approaches have been introduced. These “valid” questionnaires have been established around some of the categorizations given in table 5.7 of the previous paragraph. In turn these questionnaires are than used to refine the theories on which they are based on, in order to make an even better suited theory on presence.

Most VR research on the SoP is done by exposing participants to VEs. Many of these VEs, 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 these fundamental building blocks as a source for eliciting a SoP. Researching 2D and 3D visualization may offer new insights on eliciting a SoP.

6. Architecture in Virtual Reality

Researching the effect of 3D visualization on the SoP means introducing architecture into the realm of VR. In our 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.[58] Architecture is bound to many laws and regulations, and because of this it seldom portraits its full potential. It is imaginable that architecture can be applied to recreate our senses of a far away place just by mimicking it to a high extent. In essence we might feel ourselves present at a far away geographical location without actually being there. Although it is imaginable and it may even have been (successfully) attempted by a billionaire somewhere on earth, no conclusive scientific research exists to support it.

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. In doing so we introduce the concept of presence through transportation; people immersed in VR are thought to feel present in the VE when they have the feeling of 'being there'. It might be suggested that the better we mimic realism, the better we fool the brain and increase the SoP in the VE. And in its turn, increasing the SoP could help increase the efficacy of VRET treatments.

6.1 Requirements specification

Much research has already been done on the subject of presence and several researchers have even composed categorizations of factors that contribute to a SoP. In chapter Presence, table 5.7 shows an enumeration of factors from various researchers' point of view. Concerning the SoP, not all of these factors can be matched-up with 3D visualization. Nonetheless of the original 18 factors 12 make a fine match and can be found in table 6.1.

Table 6.1

Categorizations of factors that contribute to a SoP in relation to 3D visualization
1. Slater and Usoh[52]: a) *High quality*, high resolution information b) *Consistency* across all displays c) *Virtual body*, the representation of the user's body in the VE 2. Witmer and Singer[45]: a) *Sensory factors*, the richness of the displayed information and consistency across displays b) *Distraction factors*, how much the user is distracted from the VE c) *Realism factors*, pictorial and social realism of the VE 3. Sheridan[53]: a) Extent of *sensory information* 4. Lombard and Ditton[37]: *a) User characteristics* 5. Steuer[54]: a) *Vividness* refers to the ability of a technology to produce a sensorial rich mediated environment b) *User characteristics* refers to the individual differences in users

The given categorizations are not completely exclusive as they show similarities in some respects. Taking this into account the list of factors contributing to a SoP is reduced further to a number of eight factors, which will be discussed next.

***H**igh quality*: a minimum level of quality of graphics is necessary in order to have some influence on the level of presence felt.[59] This does not mean that the quality should be as high as possible; a resolution of 640x480 has proven to be sufficient for provoking anxiety during VRET. There are indications that widening the FoV increases the SoP.[60] The graphics involved in the creation of Delft market square were all taken with a digital SLR camera at a resolution of 3888x2592. Using a higher resolution in the beginning of the development process is necessary in order to obtain more maneuverability in a later stage of development. The eventual resolution as provided through an optical device will be much lower (approximately 800x600) and comparable to the used HMD.

C*onsistency*: the VE should provide a consistent approach of what it is trying to promote. If the consistency is lacking, the believability of that VE will be at stake, which in its turn will decrease the SoP. The VE used for this research will consist of a market square surrounded by all kinds of buildings and objects, and will thereby form one whole consistent scenario.

V*irtual body*: having a virtual representation of one's body in VR is of influence on the feeling of 'being there' and consequently on the SoP. But in order for us to achieve this would mean a costly enterprise, and therefore this factor was not accounted for in this research.

S*ensory factors*: by recreating our real-life sensory experiences (vision, sound, taste, touch and smell) as much as possible, a higher level of SoP can be achieved. The most important senses that are addressed at this moment in order to do this are vision, hearing, and touch. Of these three senses 3D visualization only addresses vision. This research will use real-life photography embedded in the VE and will in that way simulate our real-life vision sensory experience. Also 3D architecture will introduce natural looking occlusion while navigating the VE, which may further increase the SoP.

D*istraction factors*: distraction factors address the aspect of how much the user is distracted in the VE. Implementing distraction factors on the basis of 3D visualization needs a little thought. Static 3D objects may be able to elicit distraction on basis of their location, appearance and build-up. Multiple small objects can play a role in this when they are placed in the vicinity of relatively bigger objects. A subject will direct and hereby narrow his/her gaze to those smaller objects, pulling the gaze away from the bigger parts.

R*ealism factors*: graphical –and social realism have influence on the SoP. A higher level of realism means a higher feeling of presence. Though even if true realism is not achieved in the VE, perceived realism can also be of significant influence on presence.[61] Perceived realism is introduced into the VE by using a real-looking architectural build-up of the market square in Delft (e.g. through use of actual 3D objects and buildings).

U*ser characteristics*: each patient is different in probably a lot of aspects. Though not yet proven, there is some evidence that personality characteristics may affect the effectiveness of VRET.[35] Future studies should therefore investigate characteristics such as degree of absorption and hypnotizability in order to establish a successful VRET system. Although there can be a lot of difference between characters, they cannot escape the far reaching hand of society. The society as we know it is becoming a lifestyle in which gaming has started to integrate itself at the very centre of it. Many of the game engines have advanced far in mimicking realism and eventually this will bring specific graphical indoctrination with it, along with high expectations regarding the acceptance of new technology. We may not be able to change a personality, but we can adapt to its need to some extent. And introducing 3D architecture in VEs is a step in the right direction.

V*ividness*: there is empirical evidence[44] of a relationship between vividness and the SoP. For example increasing the quality of the display (e.g. a higher resolution and FoV) or adding a spatial dimension to stereo sound also increases the feeling of presence). This factor is not addressable through the build-up of a VE, but by the devices used to immerse us into it. Nonetheless care will be taken to ensure that a minimum resolution will be met when it comes to the HMD.

6.2 Gathering of reference materials from real world models

In order to start developing the VEs of Delft market square, reference materials were necessary. A visit to the market square itself was unavoidable. 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. The time frame available for taking the photographs was a small one as all shots needed to be taken before undesirable elements started appearing, e.g. people populating the market square, vans driving around, and so on. Because of this the photographs were shot early on a day, but late enough in order to catch enough lighting. Although there was no sun to see that entire day, there was enough light to complete the photo shoot successfully. The lack of a sunny sky did make slight adjustments necessary to the in-camera settings and later on to the photographs themselves for them not to look too washed away.

6.3 Structuring of graphical models

All the photograph material gathered from Delft market square needed to be looked at and structured by hand before it was used for any development activity. No photographs were discarded even though they would not be used for the development stage. They would come in handy for coordinating the placement of various objects in the final VEs. They were set apart exactly for that purpose. Other photographs were organized and divided on basis of subject (e.g. buildings, containers, benches, chairs, pillars, and other kind of objects) and goal (e.g. textures). This made it easier to overlook the whole operation and draw up an iterative approach. The work was done by first taking care of the biggest objects and then move along to the smaller ones. After all, the bigger an object the more time it would require modeling it, and taking them out first would be a good idea. Next was to start the actual development of the virtual objects.

6.4 Building objects and positioning them in the VE

The 3D modeling software package Maya from Autodesk was to be 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.

6.4.1 Buildings

Figure 6.1 Photograph taken under a certain angle

The photographs taken from the buildings surrounding the Delft market square show the buildings in a certain angle, as can be seen in figure 6.1. The buildings look like they are leaning backward. To be able to use the photographs for the intended cause, this needed to be corrected. Another consequence of the angle in which the photographs were taken, specific lines were diverging (or converging) and this needed to be corrected as well. The program Adobe Photoshop was used for this, which is a very powerful and versatile software package directed at (manipulating) digital imagery. Adobe Photoshop contains a rather handy tool for changing the perspective of images; it's called the crop tool. With the crop tool one selects the part of the image which needs to be adjusted by drawing a rectangle around it. Then the sides of the rectangle need to be readjusted in such a fashion that the angles of the rectangle's sides correspond with the chosen region measurements on the photograph. The crop tool normally just highlights the specific region chosen on an image. But when the option 'perspective' is in effect, the program recalculates the image in order to remove the present perspective altogether. As outcome we got an image with a clean frontal view of, in this case, a building. This result can be viewed in figure 6.2.

Figure 6.2 Photograph with perspective removed

Having removed the perspective present in the photographs, some additional minor adjustments were necessary in some cases (e.g. removal of obstacles). After this the photographs were ready to be used for the modeling development phase with 3D modeling software package Maya.

Maya is a very versatile 3D modeling software package, and most things can be performed in many different ways in order to come to the same end situation. That said, one needs to choose a way of working and be consistent. Using the retouched photographs in Maya was done by firstly checking their resolution in Adobe Photoshop. For the photograph in figure 6.2 this was 1760x2800 pixels. Remembering this resolution, a polygon plane was created with exactly the same aspect ratio. This way the photograph did not get deformed, and would look just like it should be. The created polygon plane initially looked like depicted in figure 6.3. In a manner of speaking, this actually represented the foundation for each 3D building.

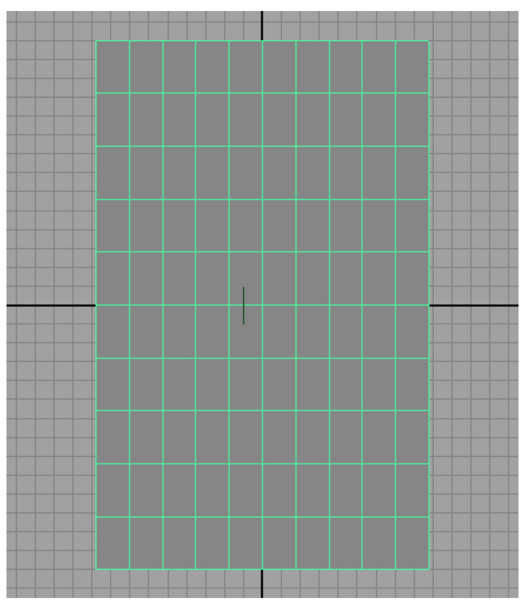

Figure 6.3 Polygon plane

The next thing to do was to project the photograph onto the created polygon plane. This was done by using the Hypershade tool in Maya. The Hypershade can be used for various purposes, but here it was used to create a texture from a photograph. In essence the photograph gets wrapped around a sphere (figure 6.4). Subsequently we projected the created texture from the photograph onto the polygon plane in figure 6.3 on the previous page, which ended up looking like the picture in figure 6.5.

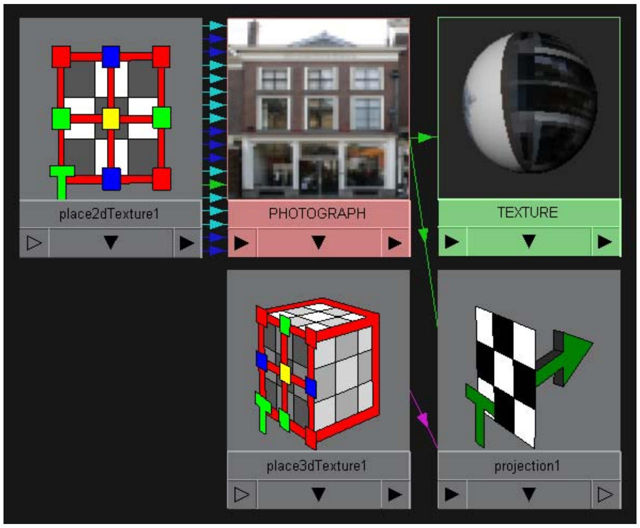

Figure 6.4 Hypershade texturing

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. The Split Polygon Tool in Maya was used for that exact purpose. Also parts of the photograph that did not belong to the building were indicated this way. The end result, in which the contours were drawn and the elements not belonging to the building had been erased, can be viewed in figure 6.6 on the next page.

Figure 6.5 Textured polygon plane

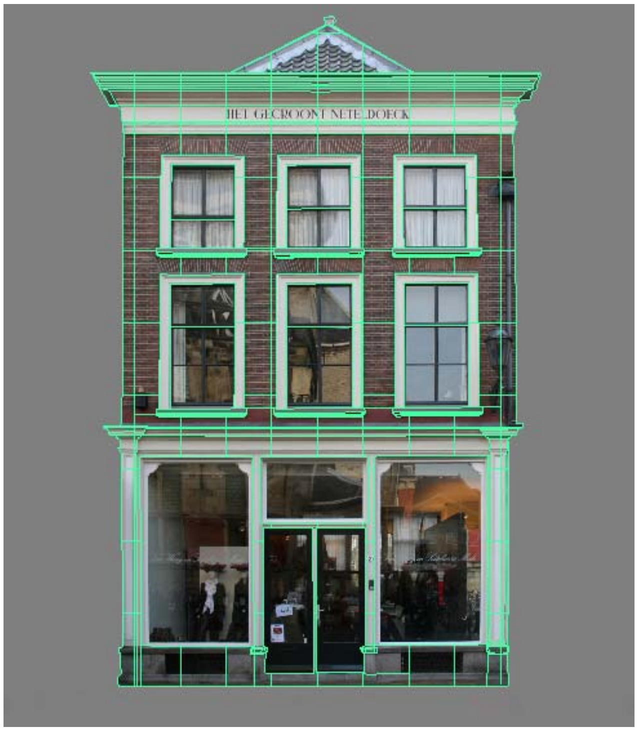

Figure 6.6 Textured polygon plane after use of the Split Polygon Tool

In figure 6.6 one can see that the shape of the polygon plane has now changed into a form resembling the contours of the building that is being modeled. In this figure many of the superfluous drawn edges have been cleaned up. This can especially be noticed around the windows, which are mostly clear of lines.

The next step was to put depth into the polygon plane, which is missing now as the polygon plane is a flat object (a polygon plane resembles a sheet of paper). Depth is a necessary component for creating 'real' depth in a 3D visualized VE.

Figure 6.7 Textured polygon plane after Extruding

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 can be done in various ways with Maya. One possibility is to change the positions of vertices or edges in order to change the orientation of segments of lines on the polygon plane. One other tool that Maya offers is the Extrude tool. The Extrude tool enables us to change the orientation of whole faces, i.e. the parts that are surrounded by at least three adjacent lines. These possibilities were mainly used to transform the polygon plane from the looks of a paper sheet into something that more or less represents the contours of a real building from a frontal view. In figure 6.7 three representations of a polygon plane with added depth characteristics are depicted. The most left representation 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 onto the textured polygon plane, although it is not accurate. The most right representation shows the same polygon plane as before, but now with a light source added to the scene. This image shows now a correctly aligned texture with accurate depth information concerning the front view of the building being modeled. This means that the depth information added to the polygon plane is working as it should be. But at this moment only the front view of the building was modeled to a certain extent.

Figure 6.8 Textured 3D polygon plane

Based on the contours of the front view in the form of the polygon plane, we were able to create the side views of the building. This was done by selecting the outer edges of the polygon plane and 'stretching' them backwards, slowly approximating the true form of a building. In order to select the outer edges, Maya has a tool integrated specifically for that purpose, and suitably named Select Border Edge Tool. After the edges were selected, the stretching could be started. This process was done by using the Extrude Edge tool within Maya. The end process of this can be seen in figure 6.8. The building as depicted in this figure has actually undergone more transformations than discussed so far, but they will come to pass as well.

The building so far, as depicted in figure 6.8, is actually a half building in respect to its depth. The side walls in the picture as shown had already been textured, although this process hasn't been discussed yet. In order to texture the sides of the building, Adobe Photoshop was used once again. With this program the original photograph (with the perspective already removed) was used to extract a part that could be used to create a texture. In this case the sides of the building existed of mostly bricks, but the upper part also existed in the form of an ornamental design. For both these parts textures needed to be developed.

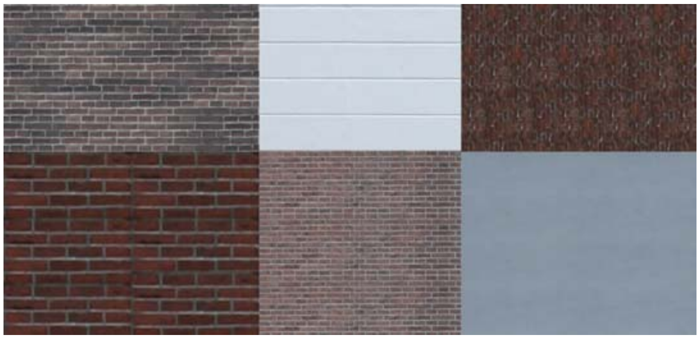

Figure 6.9 Various created textures

By extracting a little part of the photograph that resembled the sides of the building the most, we were able to create a larger usable texture. This was done by multiplying the smaller part into a larger one. One needed to pay attention to the fact that this could create sharp separations in the texture that was being created. The primary small part needed to be copied in such a way that this is avoided. Even though a lot of effort was put into this, it could still happen. Adobe Photoshop has a lot of tools to its disposal which can be used to take care of this. Examples of textures can be seen in figure 6.9. Using these textures more realism and accuracy towards the real world was added to the modeling.

Now that the building was coming on nicely, a few elements still needed to be adjusted. The roof for example needed to be in an angle in relation to the front view of the building. After changing this, some roofs had additional elements that needed to be modeled; chimneys, dormers, or other kind of ornaments for example. And all these needed to be modeled and afterwards textured as well. For all these elements additional textures needed to be created, paying attention to blend them in with the rest of the model.

As each building has its own characteristics, the modeling process could not be standardized easily and took up a lot of time. One of the buildings might have rectangular windows, whereas another one had rounded ones. And a third might even have windows with blinds installed on top of them. The same goes for the textures, as every building had a certain color intensity they could not be exchanged without any thought between the various buildings.

A few examples of different characteristics can be viewed in the following figures (6.10 to 6.13). They represent the time consuming factor in the modeling process.

Figure 6.10 Extruding woodwork

Figure 6.11 Umbrella like brick architecture

Figure 6.12 A large balcony

Figure 6.13 Special roof –and building design

After having completed one half of the building, one could create the other half of the building through duplication. In this way the building would have a modeled view from all possible sides, which would make it more versatile and usable. Having completed one building this way and moving on with the other buildings as well, one could eventually create a scenery as depicted in figure 6.10.

Figure 6.14 Scenery with multiple 3D modeled buildings

Having the buildings modeled and textured, it was time to move on to the rest of Delft market square.

6.4.2 Objects

The starting blocks for modeling the objects are not polygon planes as used for modeling the buildings, but instead polygon primitives are used. Figure 6.15 depicts a few of these basic polygon primitives that can be used for modeling all kinds of objects. They form the basis for construction, as they can be transformed in many different ways. They can be changed in respect to height, size, angle, diameter, thickness, and even their appearance is subject to change (i.e. form and shape).

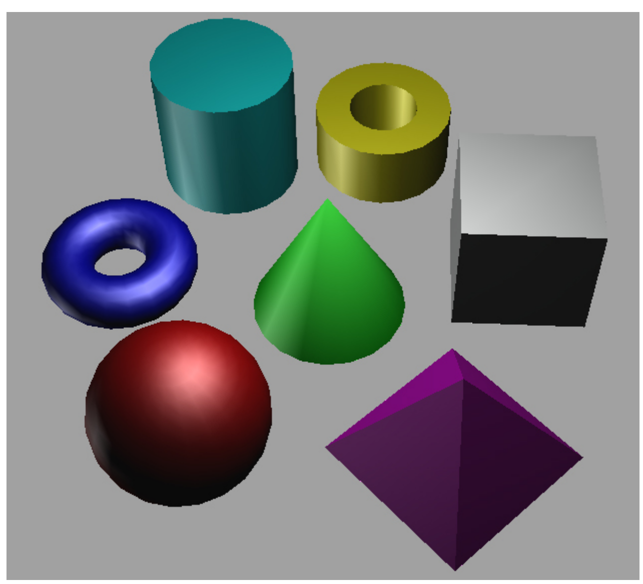

Figure 6.15 Basic polygon primitives

As stated earlier, modeling the objects was done slightly different in respect to modeling the buildings. Here the photographs were only used as an orientation aid during modeling, and would not form an integrated part of the final object design. Starting out with one of the basic polygon primitives as depicted in the previous figure, one 'sculptures' so to say his/her way towards the end result.

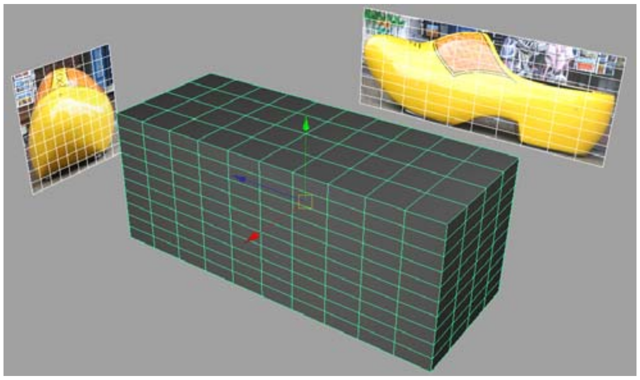

Figure 6.16 Photographs as an orientation aid

Figure 6.16 shows an example of how photographs were used as an orientation aid in the modeling process of objects. Photographs of various views of an object were put sideways of the place where one would start modeling it with one or more basic polygon primitives (a cube in this case). Having the photographs placed in the manner depicted, this provided us a constant feedback between the basic polygon primitive being 'sculptured' on and the actual object being modeled. Changing the coordinates of the vertices and edges and/or deleting them where necessary, the cube started looking more and more like the object on the photographs that were used as an aid in the modeling process.

After this process, a lot of extra work remained before the object was actually finished. Maya offers various distinct tools for all kinds of necessary adjustments. For example, in order for the (already stretched) cube in figure 6.16 to represent a wooden Dutch clog, the Extrude tool could be used to erode certain parts. Facing the fact that we started off with an angular looking object (i.e. a cube), the 'sculpture' as it was now would also look angular. And the wooden Dutch clog on the photographs is anything but angular. To transform an angular looking polygon object into a smooth looking one, Maya provides us with the Smooth tool. After al lot of modeling, textures needed to be designed for the 'sculptured' object. Some changes needed to be made to get it all look right, by tweaking all kinds of attributes like color, transparency, ambient color, incandescence, bump mapping, and so on. This was done by using the Hypershade tool and the Attribute Editor in Maya.

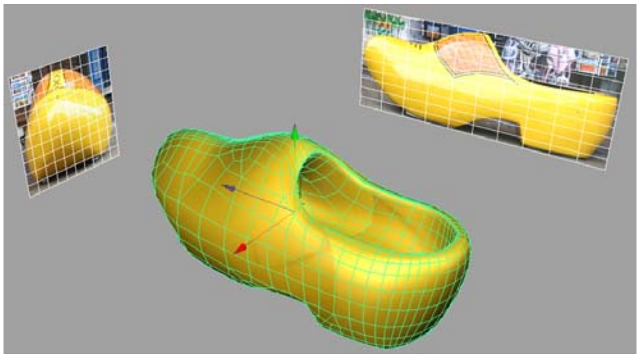

Figure 6.17 From basic polygon primitive to object

After a lot of modeling, the cube from figure 6.16 eventually looked like a real wooden Dutch clog as depicted in figure 6.17. Because of the photographs as a modeling aid, the objects were modeled in the correct proportions. This contributed to realistic consistency throughout the modeled virtual objects.

Every real-life object needs to be addressed in a different way when it comes to modeling it. For some objects one needs a polygon cube, while for others a cylinder or a pyramid will be a much better choice. And even the design tools within Maya will differ for each object. When it comes to texturing, different approaches may be used to get a better result (e.g. the Hypershade tool or UV mapping). Figure 6.18 on the next page shows a small collection of objects that was modeled. They were used to populate the virtual market square of Delft.

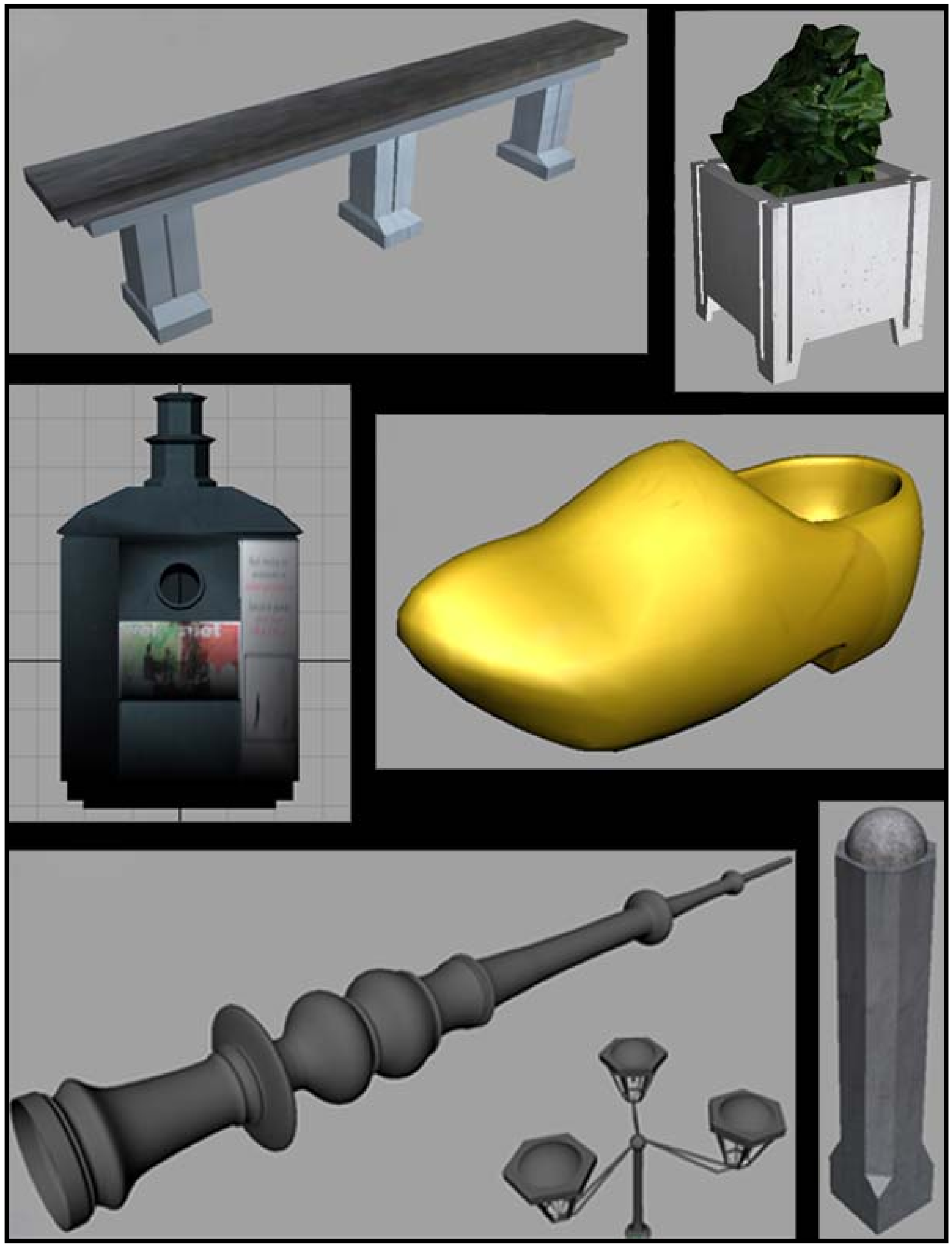

Figure 6.18 Representation of multiple objects

Not really being an object but still something that needed to be considered, was the foundation on which all the buildings and the objects would be placed. This was designed as a polygon plane on which a texture was placed resembling the original pavement of the market square in Delft.

Having the buildings and the objects modeled, they needed to be arranged in the virtual market square of Delft. The way this was done will be covered in the upcoming chapter.

Also the last step in the VE development was to enhance it with texture, lighting, sound and interaction. As this thesis focuses on 3D visualization, sound and interaction were not implemented within the VEs. And given that the rest has already been covered in the development phase, this concludes the chapter on architecture in VR.

7. 3D versus 2D visualization

The view of Delft market square formed the basis for the arrangements of the VEs 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. Regarding the various objects, a somewhat looser hand was used in placing them onto the VEs. Figure 7.1 shows a graphical representation of the top view of the developed VE which was used for evaluating 3D visualization. The VE developed for the evaluation of 2D visualization resembled this setup, although some minor adjustments were necessary for visual correctness.

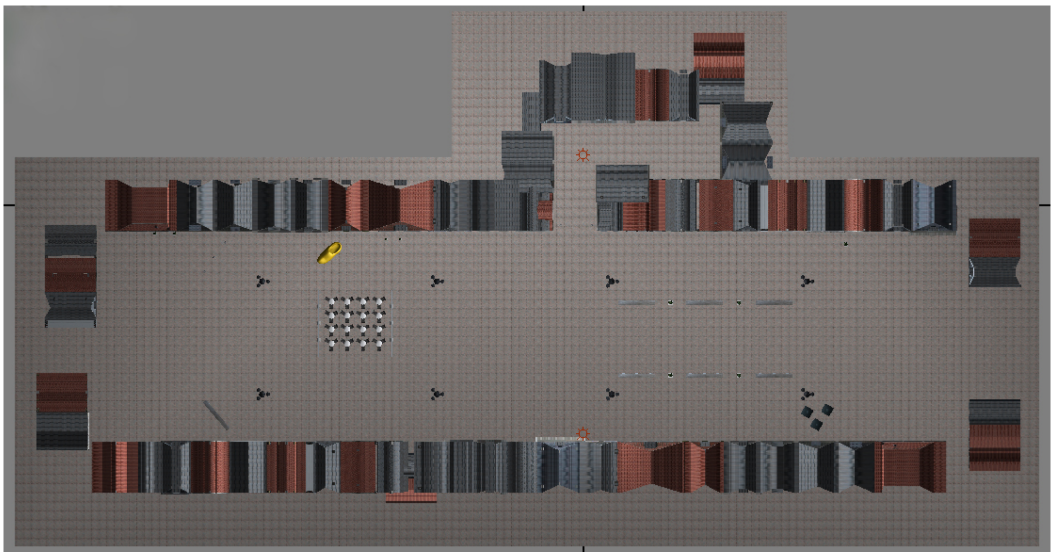

Figure 7.1 Overview of a 3D visualization of Delft market square

For the VE depicted in figure 7.1 more than twenty buildings were designed in 3D. This was enough to cover one half of the virtual market square. For the other half of the market square the same buildings were used, but to avoid too much resemblance they were arranged in a different consecutive order. This was done due to efficiency reasons, and also considering the time which was needed to model them. In addition to these 3D buildings –and objects, two large flat (2D) buildings were present on either far side of the virtual market square. Because of their ‘flat’ nature they were not visible from the top view of the VE. As those two buildings were placed in direct view of the rest with no way to pass them, they were not modeled in 3D. In addition to the market square a side alley was constructed, making it possible to wander off from the main market square.

Because of the simple character in respect to development time for the VE used for 2D visualization, the vast majority of depicted buildings was unique. The objects were the same for both developed VEs, and they were all 3D modeled.

To be able to view the VEs in real time, all the developed models in Maya needed to be exported to an external software package which enabled us to do just that. For this thesis real-time 3D application Quest3D was chosen as candidate, although it was abandoned in favor of another 3D application named Vizard. Quest3D did not have a problem with HMDs with two video inputs (two video streams directed separately to the displays in front of the eyes), as they are supported through a building block called StereoRender (with horizontal split). The reason for abandoning Quest3D lied in the fact that it leaned heavily on external driver support for software stereoscopic viewing through HMDs with only one video input. And this is where it went wrong due to numerous reasons. The only graphic cards that support HMDs with only one video input are those from the company NVIDIA. This of course would not pose a threat as they are widely available, provided that there is a good driver support. After a lot of testing of different combinations of drivers (a specific mix of two different drivers was necessary) this proved not to be the case. This left us two viable options. One option was to continue with Quest3D and revert to using an old HMD model with two video inputs (the Cybermind Visette Pro). Considering the low resolution this HMD has (640x480), the 3D visualized VE would lose a lot of its 3D 'signatures'. The other option was to choose a different 3D application which would lean less on external driver support for software stereoscopic viewing and support hardware stereoscopic viewing. This was the only option that would enable us to use the newer HMD model from eMagin (the z800 3DVisor) which has a resolution of 800x600. As Vizard also supports stereoscopic viewing through hardware (only NVIDIA Quadro graphic cards support stereoscopic viewing through hardware), the second option was chosen. This also proved to be problematic to set-up, nonetheless in the end it did work. As it is, a lot of time was spent using Quest3D, therefore the written documentation concerning Quest3D will be added to this thesis and can be found in appendix A as reference material.

7.1 Vizard

Vizard is brought on the market by the company WorldViz, and is put onto the market as a development application for interactive real-time 3D environments.[62] It is used by a wide variety of people, including designers, researchers, educators, manufacturers, and other professionals. In our case, Vizard will enable us to build a VE which we will be able to walk through by using a HMD. Vizard uses a development strategy based on the scripting language Python, which looks as depicted in figure 7.2. The given code represents adding two ducks to a scene, each in a different color so that they are distinguishable.

```
childDuck = viz.add('duck.wrl')
childDuck.color(viz.SKYBLUE)
worldDuck = viz.add('duck.wrl')
worldDuck.color(viz.RED)
```

Figure 7.2 A piece of code from a Vizard tutorial

7.1.1 The Vizard project

In order to set up the Vizard project it was necessary to import the 3D models built with Maya into Vizard. This proved to be a difficult task. Maya has a set of standard exporters to its disposal, but none of them exported directly to a format that Vizard understands without malfunctions. After a lot of trials gone bad and a lot of research on the matter, it was necessary to use an additional program called PolyTrans from the company Okino.[63] This software package is essentially a computer graphics importer/exporter on an industrial scale. And most importantly it understands Vizard's main format, which is VRML (Virtual Reality Modeling Language). Having found the correct export format within Polytrans, the next worry was to choose the most compatible opposite import format from within Maya. After a lot of testing, this proved to be the OBJ format. Specific parameters needed to be adjusted within PolyTrans to have a perfect alignment between Maya, PolyTrans and Vizard, but eventually everything worked as hoped for.

Having found a way to export the 3D models from Maya to Vizard through PolyTrans, it became possible to show them within Vizard. The next step was to write a script for running the VE that had now been set up. This script is depicted in figure 7.3 on the next page, along with information on each variable initiated.

Only a small part needed to be scripted, mainly on the subject of stereoscopic viewing, positioning, tracking and navigation. Most of the work was already done in Maya. In order for the VE to be viewed with stereovision through the HMD, the view of the VE needed to be separated into two slightly different frames. Each frame was sent to a different eye, creating the illusion of depth. By adding support for the HMD's tracking ability, an observer was able to look freely around him/herself in the VE. An additional way of navigation next to the mouse was integrated by predefining a few keyboard keys. In comparison to the mouse, navigation by keyboard made it easier to navigate the VE in a consistent speed.

```
import viz

#Setting up active stereo (left and right eyes rendered side by side) through hardware mode
#Initiating full screen on the monitor and HMD
viz.go(viz.QUAD_BUFFER |viz.FULLSCREEN)

#Adding support for the eMagin Z800 3DVisor tracker
sensor = viz.add('emagin.dls')
#Set position of the VE
viz.MainView.setPosition(50,0,0)
#Activate head tracking
viz.link(sensor,viz.MainView)
#Changing eyeheight of observer
viz.eyeheight( 6 )
#Changing the interpupilary distance of the eyes
viz.ipd( 0.06 )

#Initiating keyboard navigation for the VE, working simultaniously with a mouse
def mykeyboard(whichKey):
    print 'The following key was pressed: ', whichKey

    if whichKey == viz.KEY_UP:
        viz.move( 0, 0, 0.2 )
    elif whichKey == viz.KEY_DOWN:
        viz.move( 0,0 , -0.2 )
    elif whichKey == viz.KEY_LEFT:
        viz.move( -0.2 ,0 ,0 , 0 )
    elif whichKey == viz.KEY_RIGHT:
        viz.move( 0.2 ,0 ,0 ,0 )

viz.callback(viz.KEYBOARD_EVENT, mykeyboard)
```

Figure 7.3 Project code for getting the VE running

Next to this a view additional settings needed to be set, which can be seen in figure 7.4. Of these settings only a few were necessary to be changed. For observers not to walk through objects or buildings, the Collision setting needed to be set on 'on'. Also the FoV needed to be changed to be in conjunction with the HMD. As the eMagin Z800 3DVisor has a FoV of 40 degrees, this needed to be changed here as well. The other variable of the FoV is the horizontal to vertical aspect ratio and was left on default setting. All the other settings were either not needed for the VE or were already set in the script code as shown in the previous figure.

Properties	
Clearcolor	0.000; 0.000; 0.000
Collision	On
Eyeheight	5.500
Clip	0.100 1000.000
Stereo	Off
Viewdist	100000.000
IPD	0.060
FOV	40.000 1.300

Figure 7.4 Additional Vizard settings

7.1.2 Evaluation of the Vizard VE

The various buildings and objects modeled with Maya consisted of approximately 200.000 polygon faces. This could pose a problem for the graphic card, while viewing the VE through the HMD. In order to decrease the chance of this happening, all the buildings were stripped from polygon faces that would not be visible to the eye of the observer. As the virtual world was already set up, these polygon faces were easily detectable, although it proved to be quite a work. Textures of various models were adjusted in size, so that they would not pose a threat to the performance of the VE.

Running the VE it became clear that there were a few changes to be made. Certain design aspects needed to be adjusted to assure a correct viewing in the VE. Some textures needed to be altered, and a few buildings needed to be changed as well; some buildings had wholes in them, indicating mistakes in the mesh of their model within Maya. This needed to be corrected in Maya, from where it needed to be exported through PolyTrans to Vizard again. Traversing the VE, a judgment was made on the eye height which would be linked to observers' eyes. Also the speed of navigation was adjusted in such a way that the view did not 'tremble' when moving.

Objects needed to change place in such a way that an observer would not be able to get stuck while navigating through the VE. It became apparent that an observer would also be able to walk off the market square which should not happen. For this, the objects were placed in specific places, making it impossible to navigate off the market square.

Vizard does not support active shadowing through the introduction of lights (unlike Quest3D). Because of this the surfaces of the buildings and objects were evenly textured. This was a disappointment for especially some objects, as it made it virtually impossible to see their contours, making them look somewhat unnatural. Shadows would have been a helpful aspect for creating extra depth illusion, but for this thesis the 3D aspect was already present in the VE. As a trial an attempt was made to introduce shadowing through texture baking within Maya. This way the visibility of the contours would increase. This was successful to a certain extent, but it also introduced a big problem; texture baking the present textures (which are quite detailed) would imply a lot of time setting up the lighting to a perfect setting (which could only be done by trial and error as rendering needs to be done each time), and enormous necessary processing power. In essence abandoning texture baking would even the chances between the VEs, as mainly the 3D VE would profit.

Also the choice on navigation did not seem to be a good one for the upcoming experiment. As it was set up the participants would be able to look around freely in the VEs, but eventually they would have to be navigated in a certain direction. At those moments the participants would need to get detailed instructions from the external navigator, so that they would direct their gaze towards the destination points. The participants' gaze may not change until they arrive at those destinations; otherwise they would stroll off the instructed paths and would need additional directions to reach them. Giving detailed instructions at many times would affect the sense of being in the VEs. Also the necessity to keep ones gaze in a specific direction would limit participants' time of taking a good feel of the projected VE. As walking down paths in the VEs would take up approximately half of the time the participants had to explore them, this would not be a good outcome. To enable the participants to use their 'walking' time for exploration as well (being able to look around while between destinations) would double their interaction with the VEs. The navigation within Vizard needed to be reprogrammed to make this happen (see figure 7.5).

```
#Initiate path to walk with predefined settings
#MainView.goto( [+:go rgt/-:go lft, eyehight:up/down, +:to frnt/-:to bck], speed)
def onKeyDown(key):
    if key == viz.KEY_F1:
        viz.MainView.goto( [ 47, 6, 70 ],  3)
    if key == viz.KEY_F2:
        viz.MainView.goto( [ 55, 6, 85 ],  3)
    if key == viz.KEY_F3:
        viz.MainView.goto( [ 17, 6, 85 ],  3 )
    if key == viz.KEY_F4:
        viz.MainView.goto( [ 17, 6,-70 ],  3 )
    if key == viz.KEY_F5:
        viz.MainView.goto( [ 37, 6,-110 ], 3 )
    if key == viz.KEY_F6:
        viz.MainView.goto( [ 73, 6,-110 ], 3 )
    if key == viz.KEY_F7:
        viz.MainView.goto( [ 73, 6, -40 ], 3 )
    if key == viz.KEY_F8:
        viz.MainView.goto( [ 5, 6, -3 ], 3 )
    if key == viz.KEY_F9:
        viz.MainView.goto( [ -21, 6, -3 ], 3 )
    if key == viz.KEY_F10:
        viz.MainView.goto( [ -21, 6, 30 ], 3 )
    if key == viz.KEY_F11:
        viz.MainView.goto( [ -21, 6, -3 ], 3 )
    if key == viz.KEY_F12:
        viz.MainView.goto( [ 47, 6, 0 ], 3 )
    return True
viz.callback(viz.KEYDOWN_EVENT,onKeyDown,priority=-10)
```

Figure 7.5 New code for navigating the VEs in Vizard

Each of the “if”-statements depicted in figure 7.5 on the previous page, represented a path or a change in course. The numbers given to the function were the coordinates in the VEs. Also a specific speed was set in which the participants would walk down the given paths.

7.2 The experiment

The problem definition stated in the Introduction is as follows:

“Can 3D (compared to 2D) architectural visualization in VR provide us with a perceptual component in reaching a higher sense of presence?”

This problem definition was tested by use of an experiment, which was held among students from our technical university. Two groups were randomly formed and each group consisted of 10 participants. One group evaluated the 3D visualized VE, while the other group evaluated the 2D visualized VE. The experiment lasted approximately 8.5 minutes, after which the participants were given the opportunity to assess their VE trial with a questionnaire. Collecting the outcomes of the questionnaires from all participants would hopefully provide us with an answer on the subject of virtual visualization and presence.

The experiment was performed according to the *between-subjects* experimental design (separate groups exposed to different levels of an independent variable). Another choice would have been to perform the experiment conforming to the *within-subjects* experimental design (one group exposed to all the different levels of an independent variable), but this may have had certain side-effects on the experiment. The participants may experience fatigue because a large part of the experiment consisted of paying attention to the surroundings while navigating the VE. If they were to evaluate two VEs, the performance levels in the second VE may deteriorate because of this. Another concern would be habituation. Participants who habituate to their surroundings in VR may experience a lower exposure to the stimulus that is being measured (a sense of presence in our case). Also exposing the participants to both VEs may lead to altered responses, in which the participants could state that it is only obvious that a more realistic approach to the real world (the 3D visualized VE) would always be the better choice.

7.2.1 Experiment set-up

The experiment was run on a system which is mentioned in table 7.1, along with the used components such as software, hardware and peripherals. 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 researcher. Research shows that there is no significant difference concerning the SoP between self-navigation and external navigation.[64]

Table 7.1

System components
Software
Microsoft Windows XP Professional with SP3 (operating system)
Maya v7.0.3 by Autodesk (modeling)
PolyTrans v4.1.2 by Okino (interchange CG formats)
Vizard v3.10.0059 by WorldViz (development VEs)
Photoshop CS2 v9.0 by Adobe Systems (modeling)
SPSS v16.0 by SPSS Inc (statistic analysis software)
Hardware for modeling
1 x HP Pavilion dv9780:
Intel Centrino Core 2 Duo Processor T7250 @ 2,00 GHz
3072 MB DDR2 RAM @ 400 MHz
320 GB S-ATA Hard Drive @ 5400 RPM
nVidia GeForce 8600M GS (GPU)
Hardware for the experiment
1 x Dell Optiplex 755:
Intel Core 2 Duo E6750 @ 2,66 GHz
2048 MB RAM
NVIDIA Quadro FX 1700 (GPU)
Peripherals
Input:
VX Nano mouse by Logitech
Tracker built in HMD
Output:
HMD eMagin Z800 3Dvisor (stereoscopic, 40 degrees FoV, resolution 800x600)

The participants were informed about what was going to happen. They would use the HMD to view a VE, after which they would need to assess it by filling in a specific questionnaire to ascertain their SoP (this goal was uncovered after the questionnaire). They would be guided automatically between stopping points while they were immersed in the VE, so that they would walk a specific path. The paths that were taken by the participants are depicted in figure 7.6 by red lines. The room in which the experiment was held was darkened (the HMD brightness also eliminates a lot of the available surrounding light). Distracting sounds were kept to a minimum.

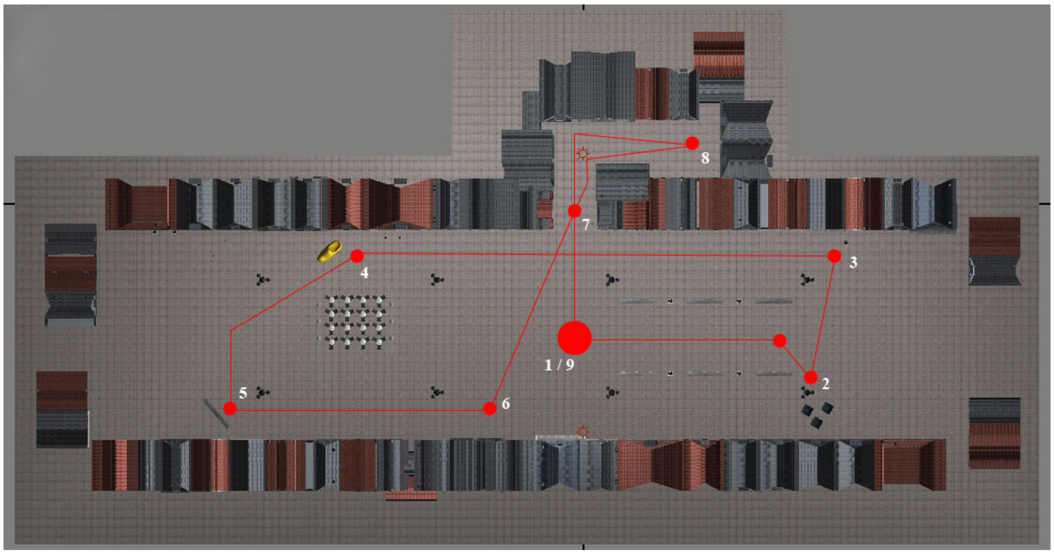

Figure 7.6 The path to walk by the participants

Figure 7.6 shows the path to walk in red lines. The red dots signify 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 VEs, they would start at the center of the market square. This way Both VEs (2D and 3D) got the opportunity to provide maximum depth information (especially the 2D VE 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 VEs 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 VE, but missing in the 2D VE. Hopefully this would trigger a difference between the two VEs in respect to a SoP. At point six in figure 7.6 a diagonal path was chosen directed towards the alley available in both VEs. The diagonal approach should favor both VEs with some points on depth information (even though the 2D VE did not have 3D buildings, the HMD would provide a stereoscopic (depth) view of the alley), although hopefully the 3D would reach higher. 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 VE should have an extra edge here, because of the 3D aspects of the buildings. 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 VEs.

A total of eight paths had been introduced for the participants to take, and nine positions in which they would be left unmoving 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 to take, are documented in table 7.2. As a total, the participants were immersed into a VE for approximately 8.5 minutes.

Table 7.2

The timing of the paths (in seconds)
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 difference between the two VEs (2D versus 3D) is easily discernible as shown in figure 7.7 below (this scenery is only for comparison and was not used in the experiment).

Figure 7.7 An example of a VE in which 2D (left) and 3D (right) buildings are present

7.2.2 Igroup Presence Questionnaire

The questionnaire used to evaluate the SoP of the participants in the two different VEs, is the Igroup Presence Questionnaire (IPQ). The reason for doing this is the fact that it is directed at evaluating immersive VR, which was the case for this thesis. The questionnaire has also been used many times before, and has a firm footing among the various questionnaires in the field of presence.[5] The IPQ consists of 14 items, covering three subscales and one additional general item ("sense of being there") not belonging to a subscale.[65] The three subscales and their respective meanings are covered by table 7.3.

Table 7.3

IPQ subscales[65]
1) *Spatial presence*: the sense of being physically present in the VE
2) *Involvement*: measuring the attention devoted to the VE and the involvement experienced
3) Experienced realism: measuring the subjective experience of realism in the VE

A graphical presentation of how IPQ tries to measure a SoP through use of the subscales is depicted in figure 7.8. The IPQ items have been included in appendix B.

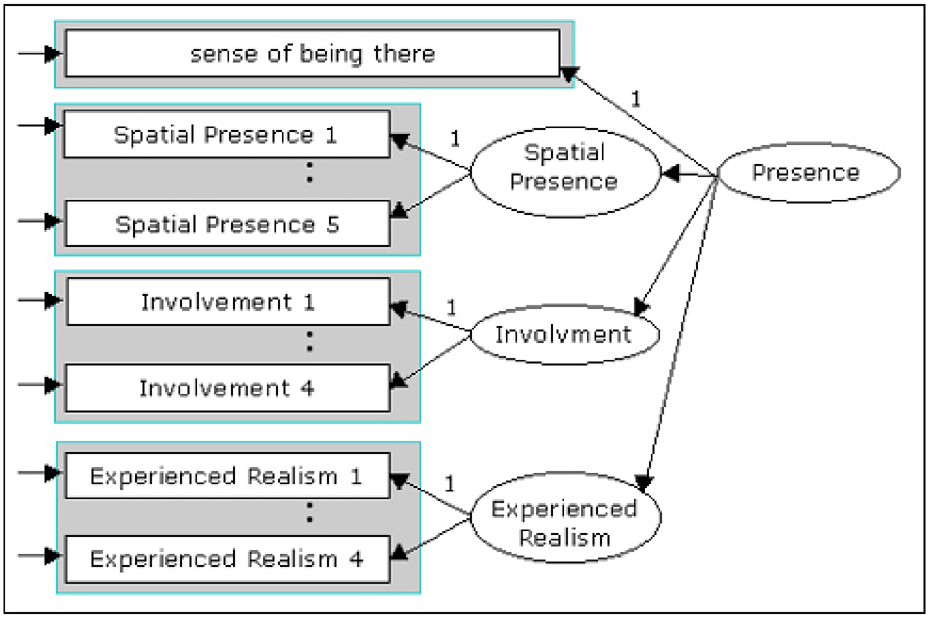

Figure 7.8 Graphical presentation of IPQ subscales[65]

As the IPQ items form an important part of the experiment, it should be offered in an easy format to the participants. This way they should have a better understanding of what they are supposed to write down. At the website that supports the IPQ questionnaire, a HTML version can be found.[66] This HTML version was used for evaluating the experiment. The digital format allowed the participants to focus more on their answer and less on the way of answering, while keeping the representation of the necessary items intact. Next to the 14 required items of the IPQ questionnaire, the participants were asked to fill in their age and gender. There was also room for them to write down additional remarks. The digital questionnaire used for evaluating the experiment can be found in appendix C; it shows the questions asked and the format in which they needed to be answered by the participants.

7.3 Results

The IPQ is based on a 7-level Likert scale. 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. There are two questions in the IPQ on which the Likert scale on position 0 portraits a non-neutral stand, favoring a certain (positive or negative) side. Even though this situation was present, the adjacent Likert items still keep their equidistant character, and no adjustments were made in respect to the collected data.

Likert scales have a few underlying distortion factors.[67] One of them is called central tendency bias, which means that the participants in the experiment may try to avoid using extreme responses on the questions asked. This would be undesirable, but there is no way to avoid it completely. Another problematic factor is acquiescence bias, which means that the participants in the experiment agree with the statements as presented. By balancing the number of positive and negative items this factor is avoidable though.

The test group consisted of twenty participants, whose age varied from 19 years up to 34 years. Two groups were formed for the experiment on the two available VEs. The average age of the group that tested the 3D VE was 24.1, whereas the average age for the group that tested the 2D VE was 23.4. All the participants were male.

As IPQ covers three subscales (spatial presence, involvement and experienced realism) and one additional general item ("sense of being there") not belonging to a subscale, the results were projected accordingly. In order to make certain that the three subscales were consistent for this type of experiment, the Cronbach's alpha was determined. The Cronbach's alpha is used to measure the reliability of a psychometric instrument (the IPQ in this case).[68] The value for α can range from negative infinity up to 1. Only the positive values actually have a meaning, and the closer α is to 1, the more reliable the psychometric instrument is.

Table 7.4

Cronbach's alpha for the three IPQ subscales			
IPQ subscale	*N of cases*	*N of items*	*Cronbach's alpha*
Spatial presence	20	5	0.826
Involvement	20	4	0.640
Experienced realism	20	4	0.796

Some professionals require, as a rule of thumb, a reliability of at least 0.70. As table 7.4 portraits, both spatial presence and experienced realism satisfy this norm. Subscale involvement falls below this norm, albeit just slightly. Showing a Cronbach's alpha very close to 0.70 indicates a positive direction in the matter of consistency, whereas its cause in falling slightly short of the set norm of 0.70 may be found in the small test group used in the experiment. Overall it can be said that the obtained numbers represent a sufficient consistency regarding the IPQ items for subscale involvement, and a good consistency regarding the IPQ items for subscales spatial presence and experienced realism, used for the experiment to measure presence.

To test for differences between the two independent groups we used MANOVA as a parametric statistical analysis method of analyzing variation and determining its significance. MANOVA is short for multivariate analysis of variance.[69] The dependent variables were based on the three IPQ subscales (*spatial presence*, *involvement* and *experienced realism*) and the general item *sense of being there*. These four classes are based on 14 IPQ items all indicated by a 7-level Likert scale, ranging from -3 (e.g. fully disagree) to +3 (e.g. fully agree). As we had two VEs (a 2D –and 3D visualized VE), the independent variable would be VR itself. For the actual calculation of MANOVA the statistical analysis software SPSS was used.[70] The scales from the 14 IPQ items were summed up to correspond with the three IPQ subscales and the general item. The results of the MANOVA analysis are shown in table 7.5 on the next page.

Table 7.5

Results of MANOVA on the IPQ subscales set for the independent variable VR

	Virtual Reality (VR)			
Measure	*F*	*Hypothesis df*	*Error df*	*p*
Overall	1.07	4	15	0.405
Spatial presence	2.46	1	18	0.134
Involvement	0.76	1	18	0.396
Experienced realism	3.69	1	18	0.071
'Being there'	1.38	1	18	0.256

Looking at the results of the MANOVA analysis in table 7.5, we were not able to find a conclusive significance in presence between the two VR environments used in the experiment. Even though the results do not show a difference for VR on significant level, the IPQ subscale *experienced realism* with p = 0.071 comes very close to the threshold of p = 0.05 to be tagged as significant. Being significant however does not tell us which of the VEs showed better results

If we look at the means of the results for the IPQ subscales and the additional general item, and compare them among the two VR environments, we could depict them graphically for additional reference material (figure 7.9). As the IPQ subscale *experienced realism* showed a promising result, we can now use figure 7.9 to see which of the two VEs in the experiment scored higher concerning the SoP.

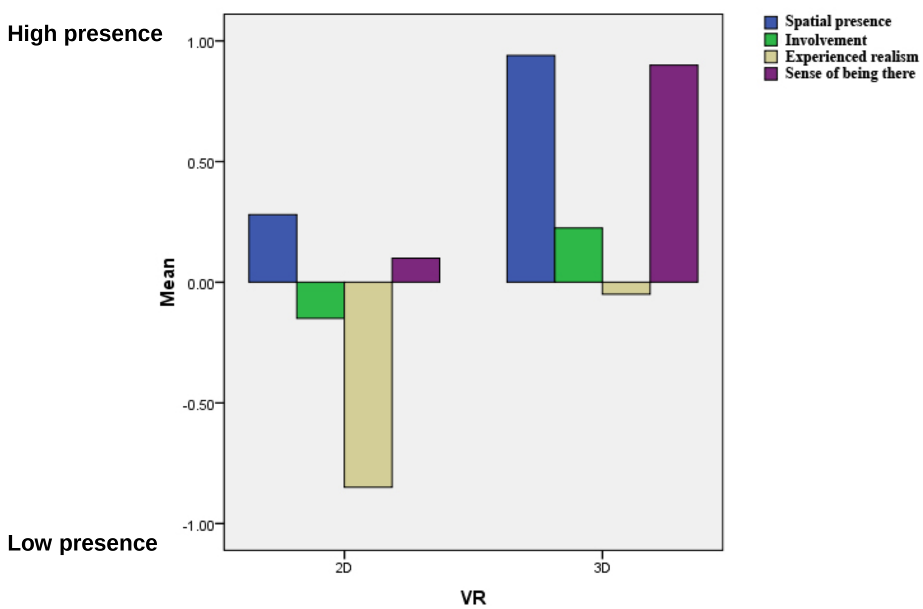

Figure 7.9 Means of the IPQ subscales and general item

Looking at the IPQ subscale *experienced realism* in figure 7.9, it shows us that the participants stated that the 2D visualized VE had a negative effect on the SoP. The participants, who were immersed in the 3D visualized VE, were more positive on the same matter; they stated that the 3D visualized VE had a neutral effect on the SoP.

A reason for having found only one dependent variable (*experienced realism*) leaning towards significance, may be found in the way we arranged the data. The Likert scales from the 14 IPQ items were summed up to correspond with the three IPQ subscales and the general item. Presenting the data this way made it amendable to distortion factors as some people may be more susceptible to extreme responses, while others are more average in their responses. As this phenomenon is undesirable, we rearranged the data in a different way, so that this posed a smaller problem. By reducing the Likert scales to an ordinal level, we combined all the responses 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. Because the rearranged data now has an ordinal character, we could not use MANOVA as a statistical analysis method to determine its significance. Instead, we recalculated the significance through use of a non-parametric test. Table 7.6 shows results obtained by the Mann-Whitney U test.

Table 7.6

Results of Mann-Whitney U test for three categories (- / 0 / +)			
Measure	*p*	*U*	*Z*
Spatial presence	0.018	23.000	-2.368
Involvement	0.264	37.500	-1.117
Experienced realism	0.058	28.000	-1,893
‘Being there’	0.166	34.500	-1.385

Subscale *experienced realism* had now reached a value really close to p = 0.05, that we could actually 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. We will use figure 7.10 to deduct which of the two VEs (2D or 3D) was better in eliciting a SoP.

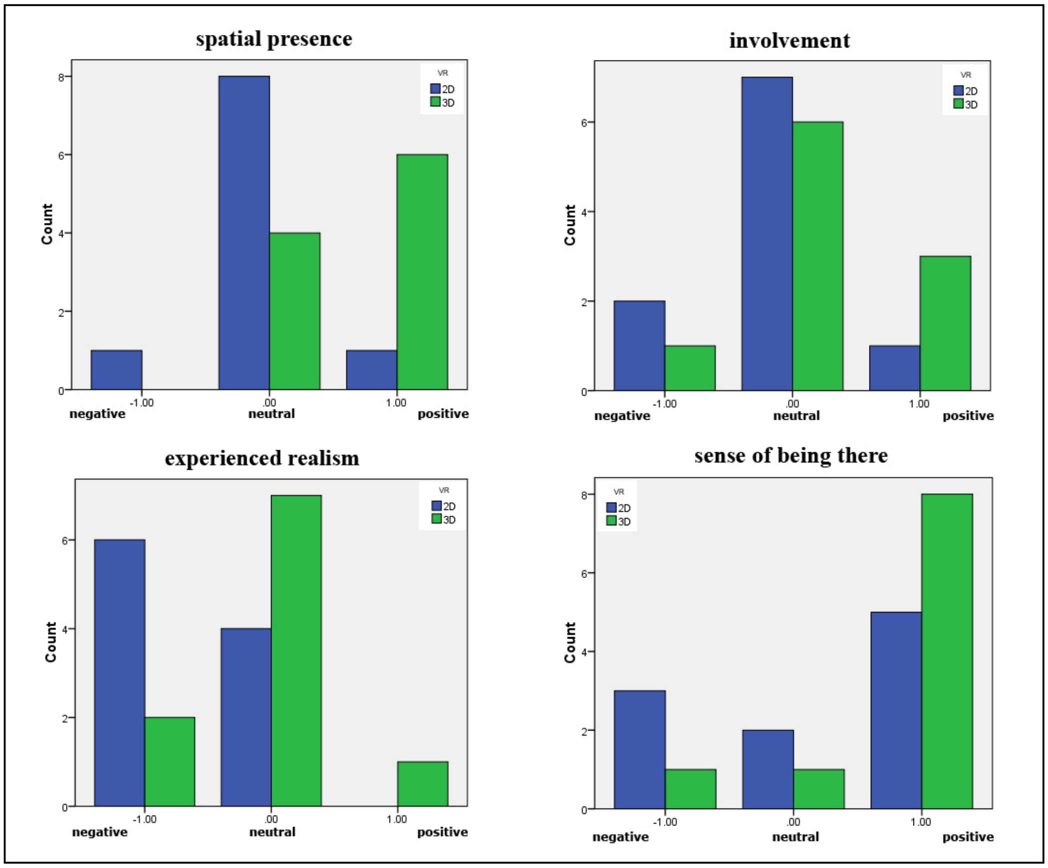

Figure 7.10 IPQ subscales plus ‘being there’ organized according to the three Likert scales

Figure 7.10 on the previous page shows graphical representations of the three subscales (*spatial presence*, *involvement* and *experienced realism*) and the additional item (*sense of being there*) according to the three categories (negative/neutral/positive). The respective categories have been generated by summing up all the responses from the participants and dividing them in three Likert scales -1.00, 0.00 and +1.00. These three Likert scales have been designed such that -1.00 and +1.00 encompass respectively all the negative and positive responses from the participants, whereas 0.00 encompasses all the neutral responses. As two IPQ subscales (*spatial presence* and *experienced realism*) showed a difference for VR on significant level, we can now see which of the two VEs (2D or 3D) is better in eliciting a SoP. Concerning *spatial presence* it is visible that the participants stated that the 2D visualized VE had a neutral effect on the SoP, whereas the participants who were immersed in the 3D visualized VE stated a positive effect on the same matter. The same applies for *experienced realism*, where the 3D visualized VE shows better results as well. The reactions from the participants who were immersed in the 2D visualized VE can mostly be found in the negative/neutral area, whereas the 3D visualized VE shows overwhelming responses in the neutral area.

8. Discussion & Conclusion

By introducing architecture into the realm of virtual reality, we were able to research the effect of 3D visualization on the sense of presence. The Delft market square was chosen as candidate for this project, which meant recreating the historic market square up to a high level of realism. By use of display optics (e.g. a Head Mounted Display) we create depth perception to our brain by showing our eyes stereoscopic 3D imagery of computer generated visual data. It might be suggested that the better we mimic realism, the better we can fool the brain and increase the sense of presence in the virtual environment. And in turn, increasing the sense of presence can help increase the efficacy of Virtual Reality Exposure Therapy treatments.

The problem definition for this thesis is as follows:

"Can 3D (compared to 2D) architectural visualization in VR provide us with a perceptual component in reaching a higher sense of presence?"

This problem definition was tested by use of an experiment, which was held among students from our technical university. Two groups were randomly formed and each group consisted of 10 participants. One group evaluated the 3D visualized virtual environment, while the other group evaluated the 2D visualized virtual environment. This way the experiment was performed according to the *between-subjects* experimental design (separate groups exposed to different levels of an independent variable).

We categorized the responses of the participants in our experiment into three response components, namely a negative, neutral and positive attitude towards a feeling of presence. This enabled us to build a view of the differences between the two different virtual environments used in the experiment; the 2D visualized virtual environment versus the 3D visualized virtual environment. The experiment was evaluated through use of the Igroup Presence Questionnaire. This questionnaire consists of 14 items, covering three subscales and one additional general item ("sense of being there") not belonging to a subscale. The three subscales are *spatial presence*, *involvement*, and *experienced realism*. Statistical analysis on these three subscales (and the additional item "sense of being there") has shown that there is a significant difference in *spatial presence* when comparing the 2D and 3D visualized virtual environments. The 3D visualized virtual environment has proven to be better in eliciting a sense of being physically present in the virtual environment. Also on the subject of *experienced realism* the 3D visualized virtual environment has shown a significant improvement over the 2D visualized virtual environment. This means that the 3D visualized virtual environment was able to elicit more subjective experience of realism compared to the 2D visualized virtual environment. On the matter of *involvement* no statistical difference was found. The subscale *involvement* measures the attention devoted to the virtual environment and the involvement experienced. Also, concerning the additional general item *sense of being there*, no significant difference was found. The general item *sense of being there* is considered to act as an overall measure on the sense of presence and therefore it is rather unusual that it is supported by only one question in the questionnaire.

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.

The sense of presence is a necessary condition for Virtual Reality Exposure Therapy to be effective in treating phobic patients. Each phobia is represented by a specific anxiety-inducing element; a person can be afraid of open spaces (agoraphobia), spiders (arachnophobia), heights (acrophobia), and so on. Without a sense of presence in the virtual environment the phobic patients will not feel anxiety when confronted with these anxiety-inducing elements. All these anxiety-inducing elements have to be presented in a suitable virtual environment, and this is where 3D architectural visualization can prove its worth. By just adding the slightest 3D accents to the virtual environment, this research showed that it is possible to elicit a higher sense of presence. And the most promising in all of this is the fact that 3D architectural visualization is employable in nearly any virtual setting, providing us with a solid foundation for developing virtual environments for Virtual Reality Exposure Therapy.

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. It is also important to note that real life Virtual Reality Exposure Therapies are implemented by guiding patients in a prescribed fashion, and that it may be impossible to put the results attained by this research to full use.

References

[1] Hodges L, Rothbaum BO, Kooper R, Opdyke D, Meyer T, De Graaf JJ, Williford JS, Presence as the defining factor in a VR application, Technical report GIT-GVU-94-5, Georgia Institute of Technology, 1994

[2] http://nl.wikipedia.org/wiki/Markt_(Delft)

[3] Hooplot FS. Design and evaluation of a new system for VRET for agoraphobia. Thesis for the Master programme Media & Knowledge Engineering at Delft University of Technology, 2005

[4] Schuemie MJ. Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy, chapter 2: Research approach. SIKS Dissertation series No. 2003-03, pp 8-9, 2003

[5] Schuemie MJ. Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy, chapter 4: Presence. SIKS Dissertation series No. 2003-03, pp 64-69, 2003

[6] http://www.igroup.org/pq/ipq/index.php

[7] Gelder M, Mayou R, Geddes J. Psychiatry: Formerly the Concise Oxford Textbook of Psychiatry, 2nd Edition Oxford University Press, Anxiety and obsessional disorders, pp 103-124, 1999

[8] Anthony S. Hale, ABC of mental health: Anxiety, *BMJ*; 314: 1886, Jun 1997

[9] Goodwin RD, Faravelli C, Rosi S, Cosci F, Truglia E, de Graaf R, et al. The epidemiology of panic disorder and agoraphobia in Europe. *Eur Neuropsychopharmacol*; 15, pp 435-43, 2005

[10] Clark DM, Salkovskis PM, Chalkley AJ. Respiratory control as a treatment for panic attacks. *Journal of Behavior Therapy & Experimental Psychiatry*, 16, pp 23-30, 1985.

[11] Vandereycken W, Hoogduin CAL, Emmelkamp PMG, Handboek psychopathologie, deel 2 klinische praktijk; 15, pp 318-341

[12] http://www.behavenet.com/capsules/disorders/anxietydis.htm

[13] http://www.adaa.org/GettingHelp/AnxietyDisorders/Panicattack.asp

[14] Robins LN, Regier DA. *Psychiatric disorders in America: the Epidemiologic Catchment Area Study*. New York: The Free Press, 1991

[15] Westphal CFO. Die Agoraphobie, eine neuropathische Erscheinung. Archiv für Psychiatrie und Nervenkrankheiten, Berlin; vol 3, pp 138-161, 1871-72

[16] http://www.jaronlanier.com/general.html

[17] The American Heritage® Dictionary of the English Language, Fourth Edition by Houghton Mifflin Company, 2006

[18] WordNet® 3.0 by Princeton University, 2006

[19] The American Heritage® Science Dictionary by Houghton Mifflin Company, 2002

[20] The American Heritage® New Dictionary of Cultural Literacy, Third Edition by Houghton Mifflin Company, 2005

[21] Stein B, Wallace M, Meredith A. Neural mechanisms mediating attention and orientation to multisensory cues. *The cognitive neurosciences.* Cambridge: M.I.T. Press. pp 683-702, 1995

[22] Stein E, Meredith A. *The merging of the senses.* London: MIT Press, 1993

[23] Schuemie MJ, Bruynzeel M, Drost L, Brinckman M, De Haan G, Emmelkamp PMG, Van der Mast CAPG. "Treatment of Acrophobia in Virtual Reality: a Pilot Study". *Conference Proceedings Euromedia 2000,* May 8-10, Antwerp, Belgium, pp 271-275, 2000

[24] Lindeman RW, Page R, Yanagida Y, Sibert JL. Towards Full-Body Haptic Feedback: The Design and Deployment of a Spatialized Vibrotactile Feedback System, *Proc. of ACM Virtual Reality Software and Technology (VRST) 2004*, Nov. 10-12, Hong Kong, China, pp 146-149, 2004

[25] Noel S, Dumoulin S, Whalen T, Ward M, Stewart JA, Lee E. A breeze enhances presence in a virtual environment. Haptic, Audio and Visual Environments and Their Applications. HAVE 2004. Proceedings, The 3rd IEEE International Workshop on Volume, Issue 2-3 Oct. pp 63-68, 2004

[26] Wessel M. Pioneering research into Brain Computer Interfaces, Master of Science thesis, Man-machine interaction group, Delft University of Technology, 2006

[27] http://medical-dictionary.thefreedictionary.com/kinesthesia

[28] Haines DE (editor); Fundamental neuroscience, chapter 16: The Somatosensory System I: Discriminative Touch and Position Sense. Churchill Livingstone Inc., United Kingdom, pp 219-235, 1997

[29] Van der Mast CAPG. Technological challenges and the Delft virtual reality exosure system. Proc. 6th Intl Conf. Disability, Virtual Reality & Assoc. Tech., Esbjerg, Denmark, pp 83-90, 2006

[30] Emmelkamp PMG, Krijn M, Olafsson RP, Biemond R. Virtual reality exposure therapy of anxiety disorders: A review, *Clinical Psychology Review,* 24, pp 259-281, 2004

[31] Foa EB, Kozak MJ. Emotional processing of fear: exposure to corrective information. *Psychological Bulletin,* 99*,* pp 20-35, 1986

[32] Botella C, Villa H, Garcia-Palacios A, Quero S, Banos RM, Alcaniz M. The use of VR in the treatment of panic disorders and agoraphobia. Cybertherapy, Internet and Virtual Reality as Assessment and Rehabilitation Tools for Clinical Psychology and Neuroscience, Amsterdam, IOS Press, 2004, 2005, 2006

[33] Krijn M. Virtual Reality and Specific Phobias, cover subtitle: Welcome to the real world. The Matrix 1999, pp 27-48, 2005

[34] Schuemie MJ. Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy, chapter 3.5: Current VRET practice. SIKS Dissertation series No. 2003-03, pp 32-42, 2003

[35] Wiederhold BK, Wiederhold MD. Lessons learned from 600 virtual reality sessions. *Cyberpsychology and Behavior,* 3, pp 393-400, 2000

[36] Hodges L, Rothbaum BO, Kooper R, Opdyke D, Meyer T, De Graaf JJ, Williford JS, Presence as the defining factor in a VR application, Technical report GIT-GVU-94-5, Georgia Institute of Technology, 1994

[37] Lombard M, Ditton T. At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, 3(2), 1997

[38] Lombard M, Ditton T. Measuring presence: A literature-based approach to the development of a standardized paper-and-pencil instrument. Paper presented at the *Presence 2000 Workshop*, March 27-28, Delft, 2000

[39] Schuemie MJ, Van der Straaten P, Krijn M and Van der Mast CAPG. Research on Presence in Virtual Reality: A Survey. *Cyberpsychology & Behavior*, Volume 4, Number 2, 2001

[40] Heeter C. Being there: The subjective experience of presence. *Presence*, Vol.1, No2, pp 262-271, 1992

[41] Schloerb DW. A quantitative measure of telepresence. *Presence*, Vol4, pp 64-80, 1995

[42] Kwan Min Lee. Presence, Explicated. *Communication Theory* 14 (1), pp 27-50, 2004

[43] Biocca F. The Cyborg's dilemma: Progressive embodiment in virtual environments. *Journal of Computer-Mediated Communication*, 3(2), 1997

[44] Schuemie MJ. Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy, chapter 4: Presence. SIKS Dissertation series No. 2003-03, pp 57-59, 2003

[45] Witmer BG, Singer MJ. Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7: pp 225-240, 1998

[46] Flach JM, Holden JG. The reality of experience: Gibson's way. *Presence*, 7: pp 90-95, 1998

[47] Schuemie MJ, Van der Mast CAPG. Presence: Interacting in virtual reality? Proceedings of the Twentieth Workshop on Language Technology 15, May 19-21, Enschede, Netherlands, 1999

[48] Zahorik P, Jenison RL. Presence as being-in-the-world. *Presence*, 7: pp 78-89, 1998

[49] Gibson JJ. *The ecological approach to visual perception*. Boston: Houghton Mifflin Co., 1979

[50] Heidegger M. *Being and time* (Macquarie J, Robinson E, transl.) San Francisco: HarperCollins, 1962

[51] Schuemie MJ. Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy, chapter 4: Presence. SIKS Dissertation series No. 2003-03, pp 69-74, 2003

[52] Slater M, Usoh M. Representation systems, perceptual positions, and presence in immersive virtual environments. *Presence*, 2: pp 221-233, 1993

[53] Sheridan TB. Musings on telepresence and virtual presence. *Presence*, 1: pp 120-126, 1992

[54] Steuer J. Defining virtual reality: Dimensions determining telepresence. *Journal of Communication*, 42(4): pp 72-93, 1992

[55] http://www.newscientist.com/blog/technology/labels/ptsd.html

[56] Sheridan TB. Further musings on the psychophysics of presence. *Presence*, 5: pp 241-246, 1996

[57] O'Brien J, Büscher M, Rodden T, Trevor J. "Red is behind you": The experience of presence in shared virtual environments. Paper presented at the *Workshop on Presence in Shared Virtual Environments*, 1998

[58] http://en.wikipedia.org/wiki/Architecture#cite_note-2

[59] Krijn M, Emmelkamp PMG, Biemond R, De Wilde de Ligny C, Schuemie MJ and Van der Mast CAPG. Treatment of acrophobia in virtual reality: The role of immersion and presence. *Behaviour Research and Therapy*, 42, pp 229-239, 2004

[60] Prothero JD, Hoffman HG. Widening the field of view increases the sense of presence in immersive virtual environments. *Technical Report TR-95-2*, Human Interface Technology Lab, 1995

[61] Bouchard S, Dumoulin S, Chartrand-Labonté G, Robillard G, Renaud P. Perceived realism has a significant impact on presence. *Laboratoire de Cyberpsychologie de l'UQO*, 2006, to be found at http://www.interactivemediainstitute.com/index_conf.html

[62] http://www.worldviz.com

[63] http://www.okino.com/default.htm

[64] Schuemie MJ. Human-Computer Interaction and Presence in Virtual Reality Exposure Therapy, chapter 5: Patient's user interface. SIKS Dissertation series No. 2003-03, pp 108, 2003

[65] http://www.igroup.org/pq/ipq/construction.php

[66] http://www.igroup.org/pq/ipq/ipq_english.htm

[67] http://en.wikipedia.org/wiki/Likert_scale

[68] http://en.wikipedia.org/wiki/Cronbach%27s_alpha

[69] http://en.wikipedia.org/wiki/Analysis_of_variance

[70] http://www.spss.com/statistics/

Abbreviations

MANOVA = Multivariate Analysis of Variance
2D = Two-Dimensional
3D = Three-Dimensional
BCI = Brain-Computer Interface
CAVE = Cave Automatic Virtual Environment
CG = Computer Graphics
DoF = Degrees-of-Freedom
DSM = Diagnostic and Statistical Manual of Mental Disorders
EEG = Electroencephalography
FoV = Field of View
HCI = Human-Computer Interaction
HMD = Head Mounted Display
HTML = HyperText Markup Language
IPQ = Igroup Presence Questionnaire
LCD = Liquid Crystal Display
MB = Megabyte
OEM = Original Equipment Manufacturer
OLED = Organic Light-Emitting Diode
OS = Operating System
PTSD = posttraumatic stress disorder
SLR = Single-Lens Reflex
SoP = Sense of Presence
VE = Virtual Environment
VR = Virtual Reality
VRET = Virtual Reality Exposure Therapy
VRML = Virtual Reality Modeling Language

Appendix A: Quest3D

Quest3D is brought onto the market by the company Act-3D, and is put onto the market as a development application for interactive real-time 3D environments. It is used for a wide variety of tasks, including design visualizations, architecture demos, training facilities, simulators, and more. In our case, Quest3D will enable us to build a VE which we will be able to walk through by using a HMD.

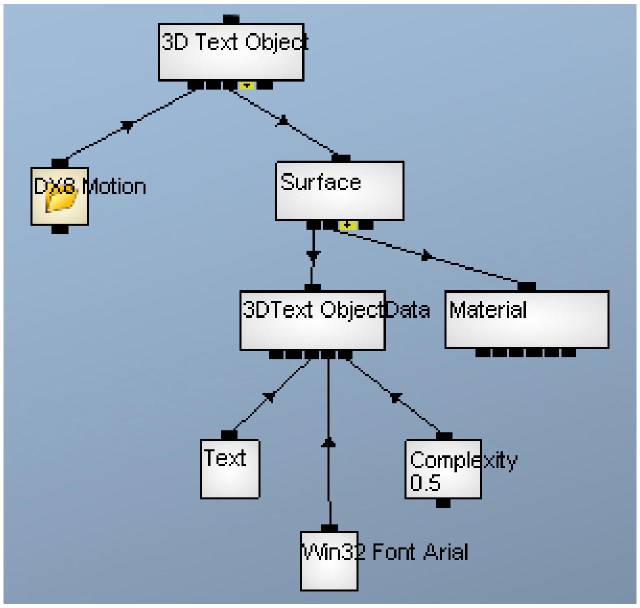

Figure A.1 Quest3D building blocks

Quest3D uses a development strategy based on building blocks, which look as depicted in figure A.1. The corresponding building blocks are than connected by linking them together. A project has a network of these building blocks connected to each other, with each building block taking up a specific function. On the positive side it's very straightforward, i.e. connecting building blocks. On the negative side, this is only the case as long as you know what you are looking for and know where to find it. And that is the hard part, as Quest3D provides little or no information on the building blocks and their functions within the application itself. Also the bigger a project is, the more confusing the network will become, as it can grow enormous.

The Quest3D project

Our Quest3D project starts with a Start3DScene block, which gets connected to a Render block (figure A.2). The Render block is necessary because the VE we will be importing has to be rendered for us to view. In order to be able to see anything, the Render block needs to be connected to a light source. In this case a Directional Light has been chosen to illuminate the VE through the Render block. Because a HMD will be used to view the VE, we will need some kind of way to look at it. This has been solved by creating a Walkthrough Camera block, which is also connected to the Render. Without this we wouldn't be able to see anything of the VE; everything would be black. In figure A.2 it can be seen that another block has been added to the Start3DScene block, which is called the Camera Logic block. This block actually consists of data which help interacting with the Walkthrough Camera. The block diagrams for both the Walkthrough Camera as well as the Camera Logic are depicted in the following figures A.3 and A.4.

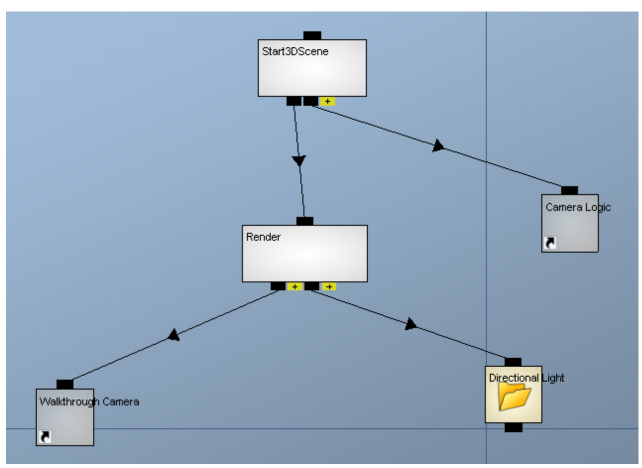

Figure A.2 Quest3D start scene

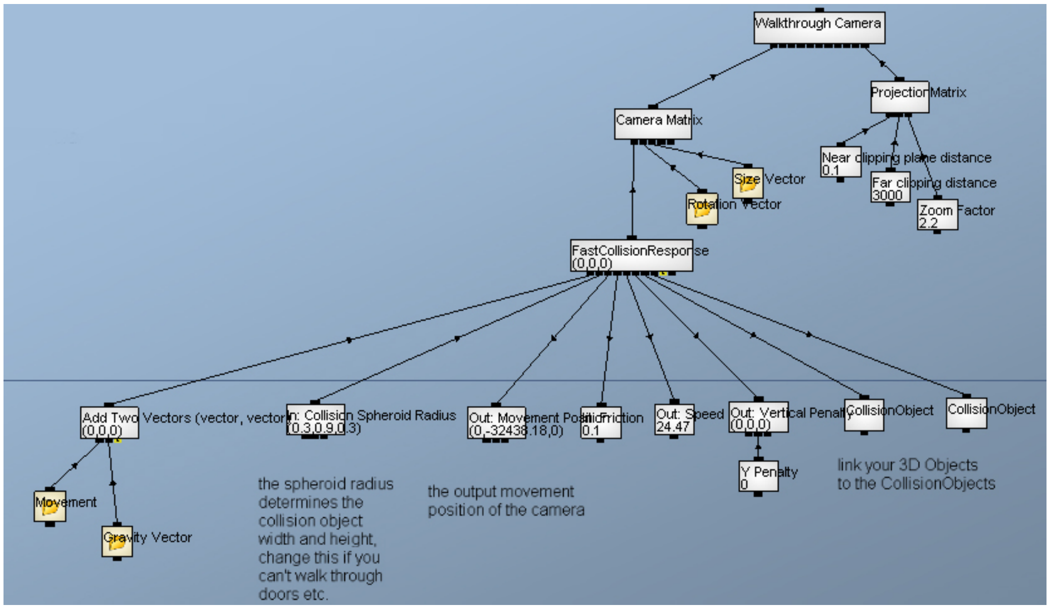

Figure A.3 Walkthrough Camera building blocks

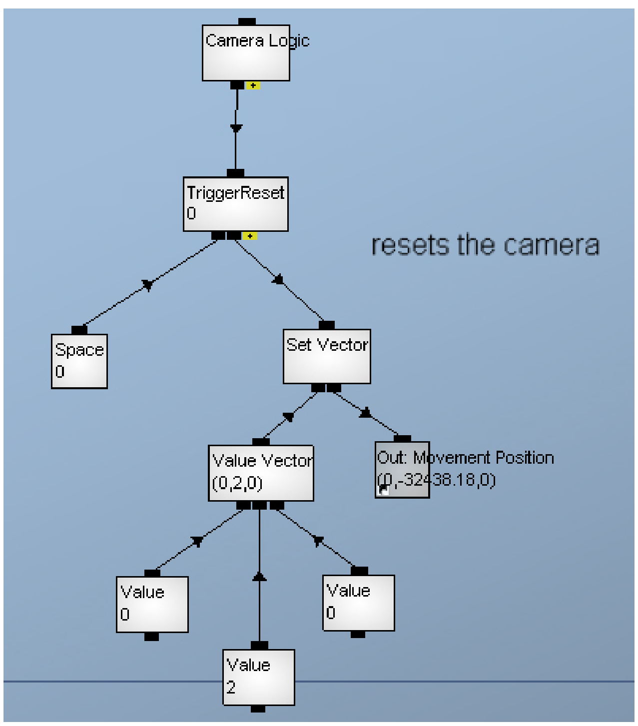

Figure A.4 Camera Logic building blocks

Within the building blocks of the Walkthrough Camera and the Camera Logic, certain variables needed to be reinstated. Without the right numbers, the camera would behave abnormally. The Collision Spheroid Radius block needed to be changed such that the camera would have an initial start on a specific coordinate and a specific height. Due to the gravity that is present in the VE (just like in the real world), the camera would start on its initial point, but would start falling through our scene faster and faster, with no way to stop it or take control over it. That is why we also needed to change the Movement Position block. It's also this same block which will be used to keep the camera at eye height, in order for a viewer to see the world at the right height. Next to this the Collision Object blocks need to be linked to our modeled objects. This is necessary for the camera to work properly, so the participants would not be able to walk through the objects them and beyond. And this is not the way it should be. For the walkthrough camera the Projection Matrix block is of great importance. It is used for handling the following sub blocks: Near clipping plane distance, the Far clipping distance, and the Zoom Factor.

The Near clipping plane should be set very low because normally we can look in the distance and yet see the ground before us close by. If we set this parameter too high, the HMD would only show the part we are looking at and less of our surroundings. Unlike with the Near clipping plane, the Far clipping plane should be set much higher. It enables us to see in the distance, without the environment "falling off", i.e. disappearing. The Zoom Factor is as the name implies used for zooming in, and it should be set to a low number to reach a comparable human view of the surroundings.

To be able to have the right lighting effect in the VE, another light source is added to the whole, and attached to the Render block. The Directional Light block and its sub blocks are depicted in figure A.5. All the parameter sub blocks of the Directional Light are parameters which are used for changing the effect the light source emits.

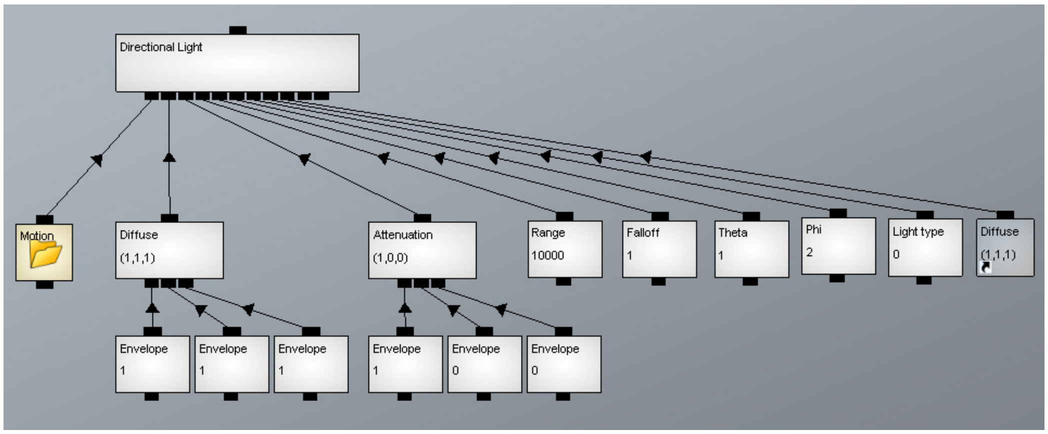

Figure A.5 Directional Light

An overview of the Quest3D project as it stands is depicted by figure A.6.

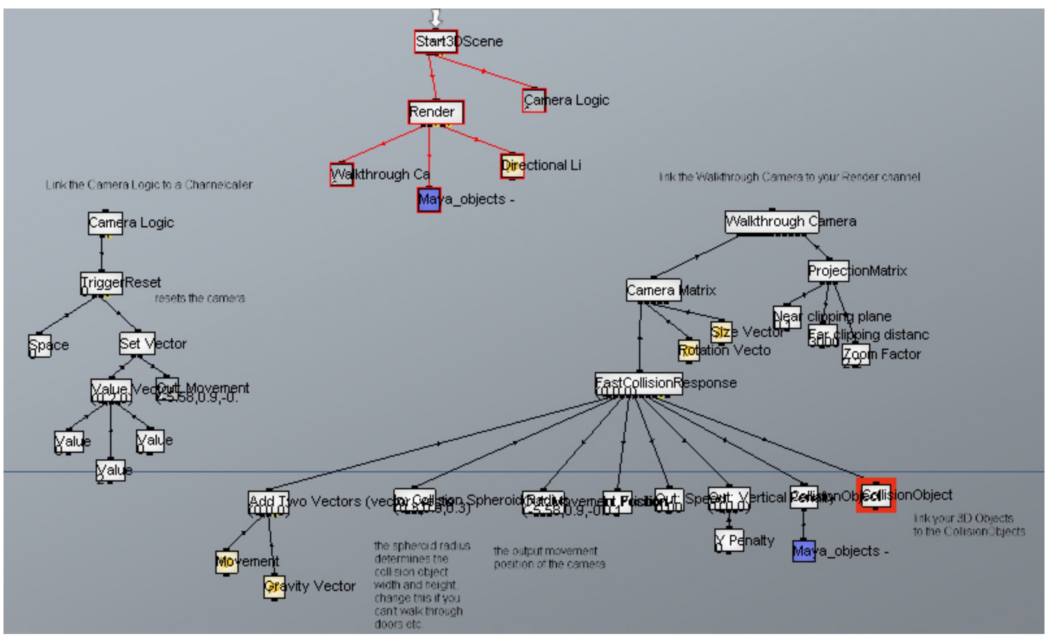

Figure A.6 Overview of the Quest3D project

Even though the project has been developed as shown in the previous figure, some parameters needed to be set by viewing the direct results in the scene. Good examples are the walkthrough camera and the light sources used in the VE.

Importing the 3D models

The Quest3D project has been set up. Now it is necessary to import the 3D models built with Maya into Quest3D. This proved to be a very difficult task. Maya has a set of standard exporters to its disposal, but none of them export directly to a format that Quest3D understands. After a lot of trials gone bad and a lot of research on this matter, it was necessary to use an additional program called PolyTrans from the company Okino. This software package is essentially a computer graphics importer/exporter on an industrial scale. And most importantly it understands Quest3D's main format, which is DirectX. Having found the correct export format within Polytrans, the next worry was to choose the most compatible opposite import format from within Maya. After a lot of testing, this proved to be the OBJ format. Specific parameters needed to be adjusted within PolyTrans to have a perfect alignment between Maya, PolyTrans and Quest3D, but eventually everything worked as hoped for.

Having found a way to export the 3D models from Maya to Quest3D through PolyTrans, it became possible to connect the objects to the started project. A graphical output is shown in figure A.7. As the information on the Maya models depicted by Quest3D do not fit on one screen, a shortcut was created.

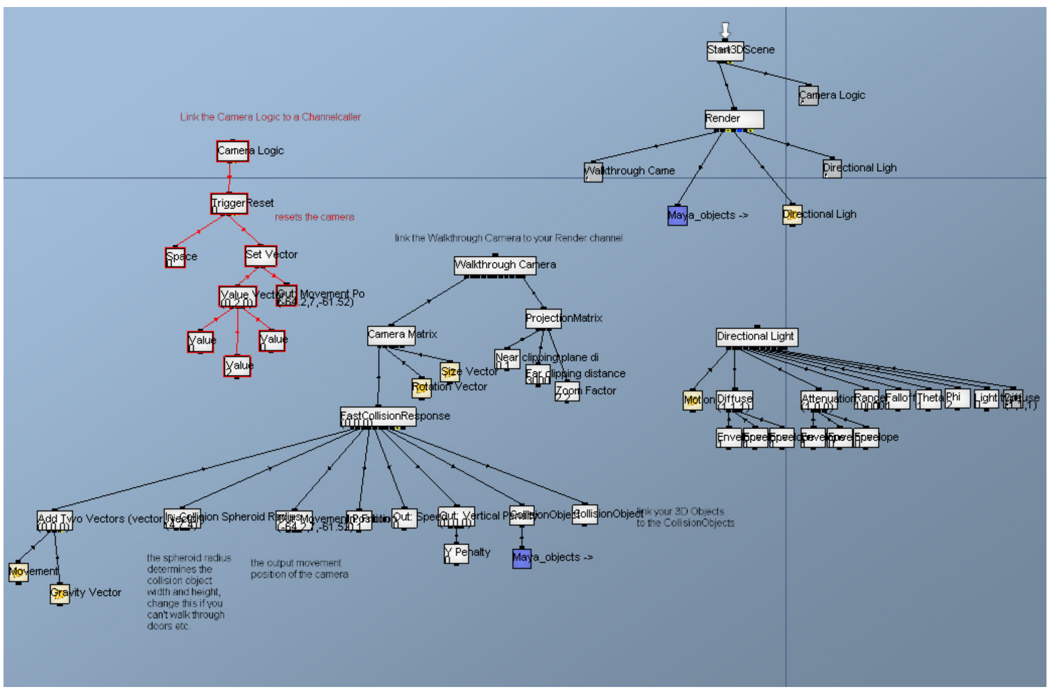

Figure A.7 Total overview of the Quest3D project

The reason for abandoning Quest3D lies in the fact that it leans heavily on external driver support for software stereoscopic viewing through HMDs with only one video input. After a lot of testing different combinations of drivers (a specific mix of two different drivers was necessary), it was impossible to get stereoscopic viewing working due to an unstable driver support. Therefore another 3D application (Vizard) was used instead.

Appendix B: IPQ items

Number	PQI/II Nr. (internal)	IPQ item name	shortcut	loading on ...	English question	English anchors	Copyright (item source)
1	s62	G1	sense of being there	PRES	In the computer generated world I had a sense of "being there"	not at all--very much	Slater & Usoh (1994)
2	s44	SP1	sense of VE behind	SP	Somehow I felt that the virtual world surrounded me.	fully disagree--fully agree	IPQ
3	s30	SP2	only pictures	SP	I felt like I was just perceiving pictures.	fully disagree--fully agree	IPQ
4	s28	SP3	not sense of being in v. space	SP	I did not feel present in the virtual space.	did not feel--felt present	???
5	s31	SP4	sense of acting in VE	SP	I had a sense of acting in the virtual space, rather than operating something from outside.	fully disagree--fully agree	IPQ
6	s33	SP5	sense of being present in VE	SP	I felt present in the virtual space.	fully disagree--fully agree	IPQ
7	s64	INV1	awareness of real env.	INV	How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?	extremely aware-moderately aware-not aware at all	Witmer & Singer (1994)
8	s37	INV2	not aware of real env.	INV	I was not aware of my real environment.	fully disagree--fully agree	IPQ
9	s40	INV3	no attention to real env.	INV	I still paid attention to the real environment.	fully disagree--fully agree	IPQ

10	s38	INV4	attention captivated by VE	INV	I was completely captivated by the virtual world.	fully disagree--fully agree	IPQ
11	s48	REAL1	VE real (real/not real)	REAL	How real did the virtual world seem to you?	completely real--not real at all	Hendrix (1994)
12	s7	REAL2	experience similar to real env.	REAL	How much did your experience in the virtual environment seem consistent with your real world experience ?	not consistent-moderately consistent-very consistent	Witmer & Singer (1994)
13	s59	REAL3	VE real (imagined/real)	REAL	How real did the virtual world seem to you?	about as real as an imagined world--indistinguishable from the real world	Carlin, Hoffman, & Weghorst (1997)
14	s47	REAL4	VE wirklich	REAL	The virtual world seemed more realistic than the real world.	fully disagree--fully agree	IPQ

Appendix C: IPQ in digital form

SURVEY ON EXPERIENCES IN VIRTUAL WORLDS

IPQ. An igroup project

configfile: openIPQ.cfg	version: 1.00	res: 1
study: 3	lang: 2	nofcase: 1

Now you'll see some statements about experiences. Please indicate, whether or not each statement applies to your experience. If a question is not relevant to the virtual environment you used, just skip it. You can use the whole range of answers. There are no right or wrong answers, only your opinion counts.

You will notice that some questions are very similar to each other. This is necessary *for statistical reasons* . And please remember: Answer all these questions only referring to this *one* experience.

How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?

extremely aware	☐	☐	☐	☐	☐	☐	☐	not aware at all
	-3	-2	-1	0	+1	+2	+3	
				moderately aware				64/inv1/0

How real did the virtual world seem to you?

completely real	☐	☐	☐	☐	☐	☐	☐	not real at all
	-3	-2	-1	0	+1	+2	+3	48/real1/1

I had a sense of acting in the virtual space, rather than operating something from outside.

fully disagree	☐	☐	☐	☐	☐	☐	☐	fully agree
	-3	-2	-1	0	+1	+2	+3	31/sp4/2

How much did your experience in the virtual environment seem consistent with your real world experience ?

not consistent	☐	☐	☐	☐	☐	☐	☐	very consistent
	-3	-2	-1	0	+1	+2	+3	
				moderately consistent				7/real2/3

How real did the virtual world seem to you?

about as real as an imagined world	☐	☐	☐	☐	☐	☐	☐	indistinguishable from the real world
	-3	-2	-1	0	+1	+2	+3	59/real3/4

I did not feel present in the virtual space.

did not feel	☐	☐	☐	☐	☐	☐	☐	felt present
	-3	-2	-1	0	+1	+2	+3	28/sp3/5

I was not aware of my real environment.

fully disagree	☐	☐	☐	☐	☐	☐	☐	fully agree
	-3	-2	-1	0	+1	+2	+3	37/inv2/6

In the computer generated world I had a sense of "being there"

not at all	☐	☐	☐	☐	☐	☐	☐	very much
	-3	-2	-1	0	+1	+2	+3	62/g1/7

Somehow I felt that the virtual world surrounded me.

fully disagree	☐	☐	☐	☐	☐	☐	☐	fully agree
	-3	-2	-1	0	+1	+2	+3	44/sp1/8

I felt present in the virtual space.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	33/sp5/9

I still paid attention to the real environment.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	40/inv3/10

The virtual world seemed more realistic than the real world.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	47/real4/11

I felt like I was just perceiving pictures.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	30/sp2/12

I was completely captivated by the virtual world.

fully disagree	○	○	○	○	○	○	○	fully agree
	-3	-2	-1	0	+1	+2	+3	38/inv4/13

Finally some demographic questions:

Your age: [ ]

Your gender: : ○ female, ○ male

Do you have additional comments?

Questionnaire last built Thursday, May 04, 2000 23:05:25

Appendix D: Paper draft

Reaching a higher sense of presence in VR through 3D architectural visualization

E. Sabadi
C.A.P.G. van der Mast
W.P. Brinkman
Delft University of Technology
Mekelweg 4, 2628 CD Delft
The Netherlands

KEYWORDS

Virtual reality, phobia treatment, sense of presence, 3D visualization, Maya program

ABSTRACT

This thesis focuses on researching 3D visualization in VR and its possible effect on the sense of presence. Being one of the largest historic market squares of Europe, the Delft market square was chosen as the most suitable candidate for the project “VR and phobias” in researching Virtual Reality Exposure Therapy in respect to agoraphobia.
“Can 3D (compared to 2D) architectural visualization in VR provide us with a perceptual component in reaching a higher sense of presence?”
This problem definition was tested by use of an experiment, which was held among students. 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 14 items on basis of 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. One subscale 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.

INTRODUCTION

Essentially Virtual Reality Exposure Therapy (VRET) is a tool for 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. 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. VR is used to create immersive Virtual Environments (VEs) with the aim to expose patients with phobias to 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. With all the promises VRET holds, it has become a popular research item. At Delft University of Technology project “VR and phobias” has been started in order to research and develop a VRET system for treating several phobias. In an effort to find out more about what causes people to experience the sense of presence (SoP) in VR, a research 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. People afraid of dogs can simply avoid them by crossing the street, but being afraid of going to the supermarket is a more problematic issue.

Most VR research on the SoP is done by exposing participants to VEs. Many of these VEs, 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 these fundamental building blocks 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 as the most suitable candidate for the project "VR and phobias" in researching VRET in respect to agoraphobia.

THEORETICAL BACKGROUND

Agoraphobia

Agoraphobia is 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.[1] Two factors are present 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
- 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).[2] 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 [3,4,5,6,7] 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.[8, 9]. Physiological measures are directed at measuring presence through physiological changes like heart rate, skin temperature and skin conductance.[6] 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 is to develop two VEs that resemble the market square in Delft. One VE will consist of 2D surroundings placed in such a way that they emit the illusion of a 3D setting. The other VE will 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 our 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.[10] 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. In doing so we introduce the concept of presence through transportation; people immersed in VR are thought to feel present in the VE when they have the feeling of 'being there'.

An experiment with test subjects immersed into the two different VEs will be 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 VEs.

Requirements analysis

Factors that contribute to a feeling of SoP in respect to 3D visualization in VR are [3,4,5,6,7]:

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

Reference material

In order to start developing the VEs 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.

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).

Figure 1 Photograph with perspective

After this the pictures were imported into Maya (and projected onto a polygon plane, see figure 2) where additional adjustments could be made.

Figure 2 Textured polygon plane

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 3.

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 4.

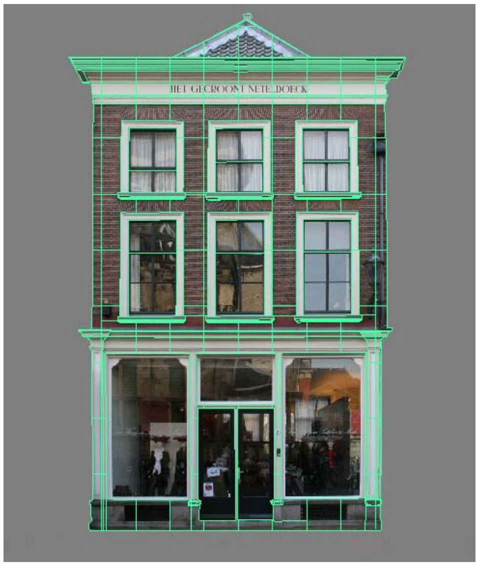

Figure 3 Building getting contours

Figure 4 Depth applied

The most left representation in figure 4 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 5 shows the end result.

Figure 5 Multiple 3D modeled buildings

After the buildings all the other objects needed to be modeled as well. These are visible in figure 6.

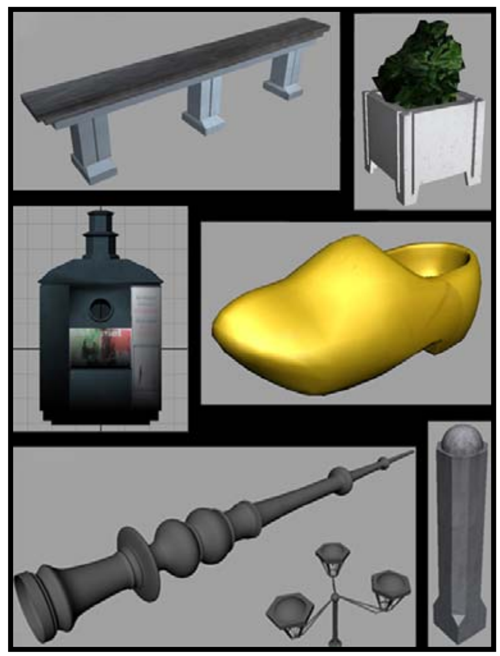

Figure 6 Modeled objects

So far the development of the 3D visualized VE. For the 2D virtual environment the same photographs were used for consistency reasons. A 2D building would look like the building depicted in figure 3. The difference with the 3D version of the building would be the lack of depth. Figure 7 shows a view of the 2D visualized VE.

Figure 7 2D buildings

The view of Delft market square formed the basis for the arrangements of the VEs 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. Regarding the various objects, a somewhat looser hand was used in placing them onto the VEs.

After the Delft market square was modeled in Maya, it needed to be imported in Vizard. Vizard (v3.10.0059) was used as a medium between the modeled virtual market square and a Head Mounted Display (HMD). This way it was possible to see the virtual market square and navigate it in real time.

THE EXPERIMENT

Experiment set-up

An experiment was held to test if the 3D architectural visualization in VR would provide a perceptual component in reaching a higher sense of presence in comparison to a 2D version of the same VE. The experiment was run on a system with Microsoft Windows XP (SP3) installed on it. The translation 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 researcher.

The experiment was held among students from the Delft Technical University. Two groups were randomly formed and each group consisted of 10 participants. One group evaluated the 3D visualized VE, while the other group evaluated the 2D visualized VE. The average age of the group that tested the 3D VE was 24.1, whereas the average age for the group that tested the 2D VE was 23.4. All the participants were male. The experiment lasted approximately 8.5 minutes, after which the participants were given the opportunity to assess their VE trial with a questionnaire. The experiment was performed according to the *between-subjects* experimental design (separate groups exposed to different levels of an independent variable).

The participants were informed about what was going to happen. They would use the HMD to view a VE, after which they would need to assess it by filling in a specific questionnaire to ascertain their SoP (this goal was uncovered after the questionnaire). They would be guided automatically between stopping points while they were immersed in the VE, so that they would walk a specific path. The paths that were taken by the participants are depicted in figure 8 by red lines.

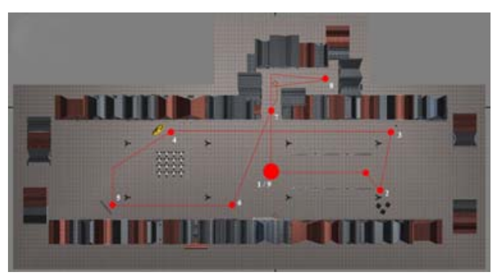

Figure 8 The path to walk

The red dots signify 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 VEs, they would start at the center of the market square. This way Both VEs (2D and 3D) got the opportunity to provide maximum depth information (especially the 2D VE 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 VEs 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 VE, but missing in the 2D VE. Hopefully this would trigger a difference between the two VEs in respect to a SoP. At point six in figure 7.6 a diagonal path was chosen directed towards the alley available in both VEs. The diagonal approach should favor both VEs with some points on depth information (even though the 2D VE did not have 3D buildings, the HMD would provide a stereoscopic (depth) view of the alley), although hopefully the 3D would reach higher. 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 VE should have an extra edge here, because of the 3D aspects of the buildings. 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 VEs.

A total of eight paths had been introduced for the participants to take, and nine positions in which they would be left unmoving 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 to take, are documented in table 1. As a total, the participants were immersed into a VE for approximately 8.5 minutes.

Table 1

The timing of the paths
9. *Path 1* → *2*: 30 s
10. *Path 2* → *3*: 15 s
11. *Path 3* → *4*: 50 s
12. Path 4 → *5*: 30 s
13. Path 5 → *6*: 25 s
14. Path 6 → *7*: 30 s
15. Path 7 → *8*: 20 s
16. Path 8 → *9*: 35 s

The questionnaire used to evaluate the SoP of the participants in the two different VEs, 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.[11]

RESULTS

The IPQ is based on a 7-level Likert scale. 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 α = 0.826, for involvement α = 0.640, and for experienced realism α = 0.796.

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, $\langle$-1, 1$\rangle$ as neutral, and [1, 3] as positive towards a SoP. The significance was calculated through use of a non-parametric test. Table 2 shows results obtained by the Mann-Whitney U test.

Table 2

Results of Mann-Whitney U

Measure	*p*	*U*	*Z*
Spatial presence	0.018	23.000	-2.368
Involvement	0.264	37.500	-1.117
Experienced realism	0.058	28.000	-1,893
‘Being there’	0.166	34.500	-1.385

Subscale *experienced realism* reached a value really close to p = 0.05, that we could actually 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.

We will use figures 9 and 10 to deduct which of the two VEs (2D or 3D) was better in eliciting a SoP.

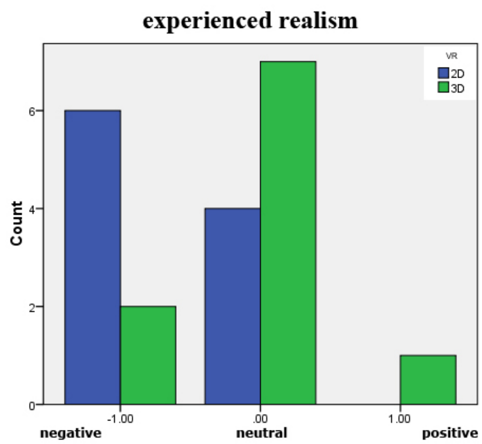

Figure 9 Experienced realism

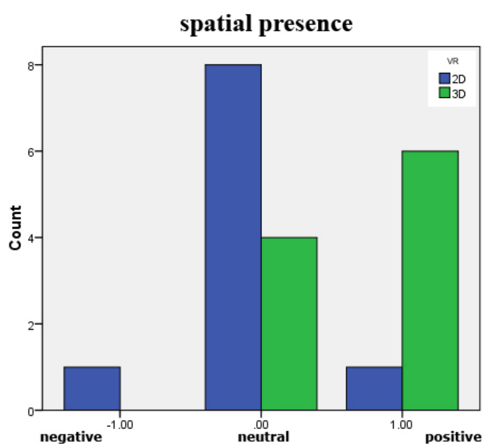

Figure 10 Spatial presence

To generate figures 9 and 10, the respective categories have been generated by summing up all the responses from the participants and dividing them in three Likert scales -1.00, 0.00 and +1.00. These three Likert scales have been designed such that -1.00 and +1.00 encompass respectively all the negative and positive responses from the participants, whereas 0.00 encompasses all the neutral responses. As two IPQ subscales (*spatial presence* and *experienced realism*) showed a difference for VR on significant level, we can now see which of the two VEs (2D or 3D) is better in eliciting a SoP. Concerning *spatial presence* it is visible that the participants stated that the 2D visualized VE had a neutral effect on the SoP, whereas the participants who were immersed in the 3D visualized VE stated a positive effect on the same matter. The same applies for *experienced realism*, where the 3D visualized VE shows better results as well. The reactions from the participants who were immersed in the 2D visualized VE can mostly be found in the negative/neutral area, whereas the 3D visualized VE shows overwhelming responses in the neutral area.

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. It is also important to note that real life Virtual Reality Exposure Therapies are implemented by guiding patients in a prescribed fashion, and that it may be impossible to put the results attained by this research to full use.

REFERENCES

1.http://www.behavenet.com/capsules/disorders/anxietydis.htm

2. Hodges L, Rothbaum BO, Kooper R, Opdyke D, Meyer T, De Graaf JJ, Williford JS, Presence as the defining factor in a VR application, Technical report GIT-GVU-94-5, Georgia Institute of Technology, 1994

3. Lombard M, Ditton T. At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, 3(2), 1997

4. Witmer BG, Singer MJ. Measuring presence in virtual environments: A presence questionnaire. *Presence*, 7: pp 225-240, 1998

5. Slater M, Usoh M. Representation systems, perceptual positions, and presence in immersive virtual environments. *Presence*, 2: pp 221-233, 1993

6. Sheridan TB. Musings on telepresence and virtual presence. *Presence*, 1: pp 120-126, 1992

7. Steuer J. Defining virtual reality: Dimensions determining telepresence. *Journal of Communication*, 42(4): pp 72-93, 1992

8. Sheridan TB. Further musings on the psychophysics of presence. *Presence*, 5: pp 241-246, 1996

9. O'Brien J, Büscher M, Rodden T, Trevor J. "Red is behind you": The experience of presence in shared virtual environments. Paper presented at the *Workshop on Presence in Shared Virtual Environments*, 1998

10.http://en.wikipedia.org/wiki/Architecture#cite_note-2

11.http://www.igroup.org/pq/ipq/construction.php