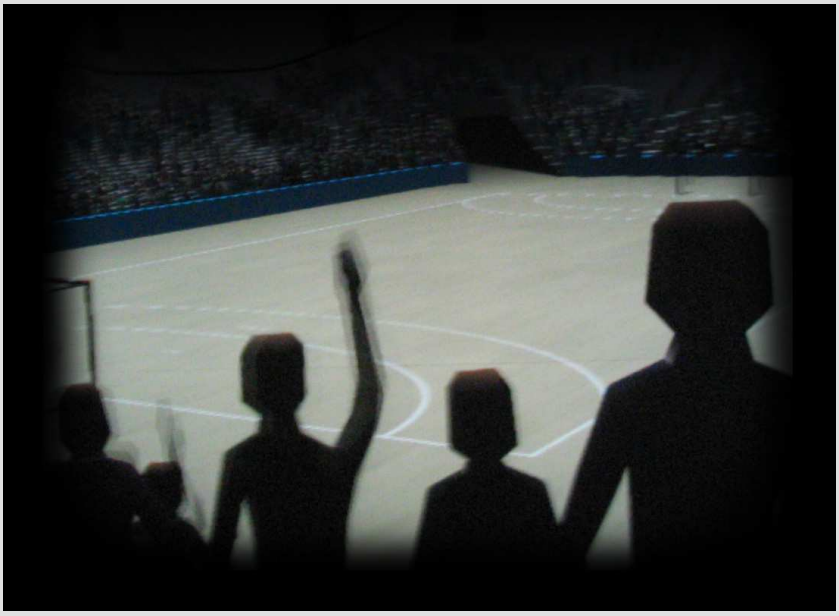
A Cross-modal enhanced Multi-Dimensional Visualization



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Supervisor: Stefania Serafin

Linda Martinussen

Aalborg University Copenhagen

Department of Medialogy

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Supervisor(s): Stefania Serafin

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Members: Linda Martinussen

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Aalborg University Copenhagen
Lautrupvang 15, 2750 Ballerup,
Denmark

Secretary: Marianne Kiær Schwaner
Phone: 9635 2471
mks@imi.aau.dk

Abstract:
Virtual environments are useful in enhancing the feeling of being present in an illusion even though the physical environment is completely different.

This focus of this project is to research in how a higher level of presence in visualizations can be evoked by utilizing virtual animations and spatialized audio, which together represent a visual-audio relationship in a cross-modal enhancement.

Three setups were tested on twelve subjects. One setup had no audio, setup 2 included stereo sounds and the last setup was using spatialized audio with eight speakers. All setups used a back projected screen, size 2,5m x 2,5m. The subjects were given the same task to create a focus for the exploration.

The scenario for the visualization is an indoor arena, containing random positioned audience, which is applied random behaviour and appearance.

The audio design is utilizing 3D panning and reverberation obtained by the RVBAP object to create spatialized audio. The audio behaviour is controlled by the visualization through OSC objects.

The tests were designed as within-subjects and ANOVA was chosen as the analysis approach supported by comparing the average of the raw test data. The results expressed that Control factors, Sensory factors and audio cues created presence, but not under the same conditions.

The unpredictable individual state of mind of the subjects in addition with a low amount of test subjects and slow navigation options produced unclear results to some extend.

Preface

This thesis is developed as documentation of the project on the 10th semester of Master of Science in Medialogy at Aalborg University Copenhagen.

For guidance, support and using time and effort in the process of realizing this project I would like to express my gratitude to

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In order to use the setup implementation on the enclosed CD-ROM, it is necessary to add some external objects for Virtools and Max/MSP first.

Virtools' extra object must be placed in the Virtools folder
(C:\Program Files\Virtools\Virtools 4.0\BuildingBlocks)

Max/MSP externals must be placed in the Max/MSP folder
(C:\Program Files\Common Files\Cycling '74\externals)

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1 Introduction

Constructions of big buildings are considered as good solutions to maintain a city in progress. Shopping centres, theatres, cinemas, sports arenas, train stations, etc. offer the citizens a great potential, making it attractive to live and work in this area. Citizens are less tempted to move away and other people will move to the city if they see social and practical advantages here. More people investing in the city through apartments, offices, companies and family activities and needs leads to new possibilities and the city can continue to grow and evolve.

It is of great importance to know the scope of an idea, before starting op a new construction project. Many aspects must be considered before the final decision, such as affordability, knowledge, equipment access, design, etc. The construction must be planned in every little detail in order to predict the appearance of the final product and evaluate the time schedule. Investors need to know the budget before approving the idea and the detailed planning can help maintaining the budget as promised.

1.1 Motivation

In the planning stage of the process of a future project, visualization and imagination are two very important aspects. On one side of the project there are the creators of the idea who have to produce a non-existing world, reflecting how it would look like in real life. On the other side the perceiver must be convinced in its prospects. The project needs to be visualized detailed enough to be correctly interpreted by others, but still with space for changes in the upcoming process of defining the aesthetics and designs and necessary changes according to technical regulations.

How the visualization is perceived can differ, according to each person’s knowledge, associations and ability in imagining something that is not real. Plan drawings can be created in 2D, viewed from top or the side. They require some ability in interpreting the technical details, which can make it complicated to survey the drawings and imagine how it would function in real life.

3D images can be created to take advantage of the depth cue, making the drawings more realistic and imaginable. However, still images only capture a fraction of a world of life which constantly changes, providing different information in an ongoing process.

The possibility of utilizing navigation in 3D visualizations has also been discovered. Still, it is often represented as a predefined walkthrough video of the model, leaving the subject only little control over the experience. When exploring an unknown area in the real world, people choose their path randomly and in their own pace and order. Providing the perceiver with similar navigation controls can make the experience personal and unique and will change the perceiver's status from being an observer to be a user.

Considering how highly audio is affecting the perception of images in the physical world, it could be motivating to operate with this cue. Utilizing audio in collaboration with graphics could provide a person with stronger cues and hence increase the feeling of being present in the virtual world. Furthermore, it would improve the chances of the person understanding the idea, as the inventors intended.

1.2 Problem formulation

Making use of multimodality together with a large freedom of navigation influences a person's connection to the virtual world by creating a larger association to the physical world. If the person feels comfortable using the visualization, it will be more intuitive to navigate around in the model. The interpretation of how the idea will function in the real world will be emphasized. Also, creating a stronger focus on the experience can downscale the attention of using tools and the perception of a technical limited virtual world.

Three main aspects are considered, in the development of an immersive visualization of a future building project, which can enhance the feeling of presence:

- Virtual animations
- Spatialized sound
- Multimodality

These aspects lead to the following problem formulation

In which degree is it possible to utilize multimodality, spatialized audio and animated virtual environments to improve the feeling of presence, when exploring the visualization of a virtual world?

There are several types of multimodality, which are described in section 4.3. The type attempted utilized in this project is called cross-modal enhancement and makes use of the visual and the auditory modality.

To validate the problem statement, a setup was implemented and subsequently tested under different audio conditions.

2 Presenting presence

The three aspects in the problem statement are used in order to create a higher level of presence in visualizations. To detect presence in a virtual environment is in some degree difficult to specify.

In the following main sub sections these four different matters of presence are elaborated

- Characteristics
- Immersion
- Interference
- Measuring presence

2.1 Characteristics

Feeling presence is a very subjective state of mind. It tells whether one is being emotionally connected to the surrounding environment. Sometimes it is possible to be so deeply busy in thinking of something completely different than where one is situated. The concentration of one thought can be so strong that it is difficult for other people to get in contact with one. The mind is being present another place.

A virtual environment is an illusion created by equipments, stimulating the senses of a person with different information loads. It is an attempt of producing a world without actual building it. To make the impression of the world convincing, presence is of great importance. Presence reflects a personal experience of the virtual surroundings in spite of being in other physical conditions (see Table 1). If the person feels dissociated to the abstraction, the experience quality is degraded. To be able to create and maintain a high level of presence feeling, some of the stimuli in the virtual world, which are reflecting the expected stimuli in a similar situation in the physical world, must be present.

"Presence is defined as the subjective experience of being in one place or environment, even when one is physically situated in another" *Witmer, B. G.; Singer, M. J.* *Measuring Presence in Virtual Environments: A Presence Questionnaire [14]*

Table 1: Presence quotation

The stimuli are perceived in different ways based on their internal connection and to their connection to the virtual environment. The person uses the information to respond and understand the virtual world, but not necessarily in the exact same way as in the physical world.

When shifting presence from the physical environment to a virtual environment, other rules should be expected according to the function and appearance of the virtual environment. The experience will differ between people, based on prior experience and knowledge within the associations created to the data load. Acceptance and adapting abilities are also affecting the experience of feeling present. Tests show that a person in a high degree is willing to accept simplified representations of virtual humans or their own body parts, e.g. arms and legs [4]. The degree of adapting to the virtual environments has also showed very positive [4] perhaps because people consider the exploration of a virtual world as similar to computer games, where it is necessary to learn some rules before being able to fully understand and use it.

"Individuals rapidly adapt to such disruptions, and learn to operate in the new conditions"

Witmer, B. G.; Singer, M. J.
Measuring Presence in Virtual Environments: A Presence Questionnaire [14]

Table 2: Presence quotation

Presence can be evoked by different elements of the virtual environment. The following three types of presence illustrate different categories [18].

- Personal presence
- Social presence
- Environmental presence

2.1.1 Personal presence

Stimuli and experience are two main dimensions in personal presence. Stimuli represent the normal feedback conditions present in the physical world, where the environment is affected by moving objects, e.g. people and cars. Supplying the senses with synthetic information feedback can stimulate the modalities and transform imagination into a realistic experience. Changes in images according to ones own movement, audio feedback on collision and tactile feedback, when touching a virtual element, are examples of stimuli which make the experience more personal.

Experience can make a person more comfortable with the setup, making one feel more in control. The person has less knowledge to gain before fully understanding the environment, creating a closer connection between person and virtual space from the beginning of the exploration.

2.1.2 Social presence

Another element of the virtual environment creating a different type of presence is response from other living systems, e.g. people, animals or animated objects, to one's presence. Through interaction between the animated elements and the person a social presence occurs.

In the physical world it is a normal condition that people are affecting each other. If one is talking to another person, some kind of respond is expected. Walking among many people, forces one to change direction many times, because the path of the people flow around you interferes with one's own. The visible affect one's behaviour has on other people's behaviour confirms being present in that space. Applying the same types of interaction to the virtual world can create a more convincing presence experience.

2.1.3 Environmental presence

Just as animated elements' respond to one's own behaviour can make the experience more realistic, an environmental respond can add to that effect. In normal conditions, elements of the environment can react to one's influence of being there. Automated systems are predefined to react in certain ways according to the surrounding behaviour. E.g. in a train a hallway door is only opened if one is making a movement at a specific area above the door. Having the environment react to one's presence in the virtual world enhances the feeling of being integrated in the imagination.

The ability to move and modify objects also creates environmental presence, e.g. open a door or drawing on a piece of paper. Interacting with the environment involves a person physically, something that is normally expected to be possible under normal conditions.

2.2 Immersion

"Immersion is a psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences"

Witmer, B. G.; Singer, M. J.
Measuring Presence in Virtual Environments: A Presence Questionnaire [14]

Table 3: Immersion quotation

Immersion is reflecting a person's subjective feeling of being a part of the virtual environment when being affected by the produced stimuli from the setup equipment (see Table 3). Computer Aided Virtual Environments (CAVE) and Head-Mounted Displays (HMD) are tools which can create fully immersed scenarios both visually and with sound because they surround the subject physically as well as in the virtual environment. Immersion can also be evoked in some degree even if not physically affected by stimuli, e.g. when a person is using the imagination to create the stimuli cues which would be expected to be present in the physical world. This type of immersion could appear e.g. when reading a book or listening to a story played on a tape or told by other people. It is relying a great deal in the individual imagination ability.

2.3 Interferences

Several parameters can decrease the level of presence when the subject explores the virtual environment. There are both internal and external parameters to account for (see Table 4). The internal parameters are the conditions of the virtual environment and the external parameters are elements from the physical environment, which can be positioned inside and outside the area of stimuli created by the equipments.

Internal		External	
Parameter	Description	Parameter	Description
Quality	LOD, textures, realism	Noise	Sounds from the physical environment surrounding the setup
Multimodality	Stimuli from different modalities affect each other	Movement	Visible people passing by the setup. Active screens.
Latency	Response time according to synchronization expectations, screen frequency	Objects	People, furniture, etc. Visible from the inside of the setup

Table 4: Interferences

2.3.1 Internal parameters

The quality of one modality which stands alone should be expected to be high to achieve its desired effect. With all the attention drawn to only one stimulus, many details become visible for a person. If perceiving stimuli from several modalities, the attention is divided and the stimuli will be perceived according to their internal connections, focusing more on the coherence than the details.

As much as the stimuli can be perceived as supporting each other, making the impression natural, they can work against each other and destroy the illusion, instead. It all depends on their expressed connection according to expected collaboration of the stimuli.

The reality appearance of the visual cues have shown to be accepted in low realism if used together with other modalities, e.g. audio and tactile [4]. The quality of audio and visual displays in a coherent perception has shown to influence the quality of one of the perceived stimuli (see Table 5).

Visual display	Auditory display	Results [10]
High quality	Medium quality	Increase in visual display quality
High quality	High quality	Increase in visual display quality
Low quality	Medium quality	Decrease in auditory display quality

Table 5: Visual-auditory display

Predefined visualizations with different frame rate have been tested together with audio effects [3]. The result showed how changing the quality in the test videos was not perceived when sound was added. On the other hand, the frame rate modifications were notable when the videos were tested without sound.

Latency can break the feeling of being present in the virtual environment. If the feedback cues occur too late according to the expected time frame, a person risk losing the natural flow and the presence feeling is interrupted.

2.3.2 External parameters

Noise from objects and people in the physical world surrounding the virtual environment can interfere with the experience because the test subjects are either disturbed in their exploration of the virtual world or include these audio cues in their impression of the setup sound.

If the subject is not fully physically enclosed in the setup, the subject might be aware of movements from people passing by the setup. The human eye detects the surroundings best if the perceived images differ and thus create motion [15]. The subject's eyes will be focusing on the virtual environment, but the human eye register motion best in the periphery of the field of view, so even having the eyes on the virtual environment, there is a risk of detecting motion from the physical world. This can change the focus from the virtual world and break the presence.

Elements from the physical world can also be a distraction even if they are static, but in a smaller extent than moving objects. The human field of view (FOV) has a range of approximately 180

degrees [23]. In the periphery of the FOV the eyes perceive fewer colours, which make the images less detailed [15]. Hence, this kind of distraction is less damaging for the experience. If the appearances of the viewable elements do not separate much from the virtual world, they might be less noticeable and possibly just ignored, because they integrate naturally in the virtual environment, when being perceived in the periphery of the eyes.

2.4 Measuring presence

According to the established quality of the parameters and their collaboration the presence level will be affected. Taking the above mentioned interference parameters into consideration can help creating a setup, which will evoke a high level of presence. Still, the experience of a virtual world is very subjective and the perception will probably always differ according to the person.

Several attempts have been made to find a precise way to measure presence over more than a decade. Physical measurements have been carried out on the user while exploring a virtual world through head-mounted displays or stereo glasses followed by questionnaires created to measure the subjective respond. Others have investigated in Breaks In Presence (BIPs) where a person register whenever one is feeling that presence is interrupted or degraded.

2.4.1 Questionnaire

The most common approach to measuring presence is making the test subjects fill in a questionnaire after the test [13] [14] [16]. It is a subjective measurement to a subjective experience and is not totally reliable. When people are tested, they are aware of it and can force the exploration to be less intuitive in the attempt of performing the test well. The answers might be based more on what the test person expect the answer would be rather that what they personally experienced it to be.

Still, since presence is a very subjective feeling to measure a questionnaire approaches people's experience within a large degree of freedom in the questions. The questions should be very carefully expressed in order not to lead the subject into answering what is thought to be correct in stead of answering based on the personal opinion. There are no wrong answers when dealing with subjective aspects. The difficult part is to be able to express clear questions without affecting the test subjects' memory of the exploration.

2.4.2 Physical reactions

Other ways to measure presence is to use equipment, which collects data based on the physical conditions happening to the body during the test. It is possible to measure the heart rate, the skin conductance and the skin temperature [2] [9] [12].

Heart rate (HR) is the most reliable of the three physical conditions because it is very sensitive to changes, resulting in a higher frequency of measurements to be used for statistical purposes. In a stressful state the heart rate will increase its speed of beats [9].

When stress produces more sweat than usual, it will affect the conductance to increase [9].The results from measuring the change in skin conductance do not differ much from each other and do not support the HR results. Since HR provides more consistent data, skin conductance must be considered as less reliable.

Changes in skin temperature are difficult to measure and not as responding as HR, which degrade the quality of data measurement results. The changes in the skin temperature occur in stressful environments, which slow down the circulation and reduce the temperature [9].

In a test using a head-mounted display, test subjects were exposed to a virtual scenario creating stress, while their HR, skin conductance and temperature change was measured [9]. After the test the subjects filled in a questionnaire. In 90% of the test results, the HR was increasing. The test results showed increased skin conductance for 95%. In 90% the skin temperature was decreased. The HR results were consistent with the results gained from the questionnaire.

[9]

Illustration 1: Measuring physical conditions of presence

They might be a good addition to the subjective measurement from a questionnaire, to see whether the results are consistent or differ from one approach to the other. However, they seem more appropriate for tests involving explorations which are differentiated a lot compared to a normal state, e.g. explorations including stress or fear. This project does not include exposing the people with extreme situations, which could produce these strong feelings and the result would not be expected to be measurable or consistent enough to be valuable.

"In the last segment of the experience, the participants tended to become more stressed perhaps due to a lack of interest in the environment, a mundane explorative task, or because the technological limits in the system become more apparent." *Brogni, A.; Vinayagamoorthy, V.; Steed, A.; Slater, M. Human factors II: Variations in physiological responses of participants during different stages of an immersive virtual environment experiment [2]*

Table 6: Immersion quotation

2.4.3 Breaks In Presence

A recent approach to measure presence is using Breaks In Presence, which is a reversed presence measurement evaluated by the user. During the test a person registers when presence is broken. Considering the extra awareness on this assignment while exploring the virtual environment, there can be a risk of diminishing the experience for the person. Having the task in mind, the person might be too much focused on the BIPs than being naturally stimulated by the virtual inputs. Further more the extra awareness of BIPs can make the person force the amount of registered breaks, since the focus is less on the exploration.

This approach has been claimed less reliable by M. Slater, who tested BIP's used with physiological response measurements, e.g. heart rate. The results indicated that the registered breaks were coursed more by stress provoked by the though of performing the BIP-task itself than by the actual presence abruptions [6].

3 Approach

Based on the research evaluations it must be considered that different situations call for different virtual environment solutions. This project does not support the idea of a general composition of stimuli creating presence, but believe in the coherent connection of stimuli, which can differ according to the focus on the particular scenario. The chosen stimuli focus and priority are based on the common associated expectations to the scenario.

"It is likely that in order to achieve presence there needs to be consistency in sensory input across as well as within modalities, but to what extent remains an open and empirical question" *Slater, M.* *A Note on Presence Terminology [7]*

Table 7: Presence quotation

If the virtual environment is focusing on user tasks and activities, tactile feedback might produce the convincing presence effect. Should the project involve auditory displays, spatialized 3D audio could be prioritized higher than a perfectly realistic rendered 3D graphics. Interactive battle games are involving rapid navigation and fast solutions in killing enemies, demanding a fast and effective graphic feedback but not necessarily rendered images in high resolutions.

"An alternate view is that the experience of presence in a VE may have aspects similar to the concept of selective attention. Selective attention *refers to the tendency to focus on selected information that is meaningful and of particular interest to the individual"* *Witmer, B. G.; Singer, M. J.* *Measuring Presence in Virtual Environments: A Presence Questionnaire [14]*

Table 8: Presence quotation

By utilizing multimodality in this project it is attempted to create personal presence. Multimodality is described in section 4.3. There is not made an effort to create social presence. However, this type of presence is simulated by creating random character behaviour, but they are not responding according the test subjects. Social presence could be added in a further development of the project by implementing user interaction, which the virtual characters would respond to. Environmental presence is represented in a few obstacles declared as collision objects, making the subject avoid walking through these objects as it would not be expected to do under physical conditions. But to provide the navigation with a greater freedom, it is possible to walk through most of the objects.

Immersion is very closely connected to presence. Feeling integrated in the virtual environment can affect the presence feeling positively, making the experience more realistic and believable [14]. The situation in this project is to approach immersion by using technology and equipment to generate information loads, simulating real life's modality inputs to create the same atmosphere as expected to be present in a similar situation in the physical world. By setting the stimuli which affect the test subject rather than relying in the subject self to imaging what was intended, the same main exploration scope is created for all test subjects.

"Cognitive psychology has convincing argued that perception is not a process of extracting information from the world via the sense, but rather a process of inferring information partly from information provided by the senses, and partly from previous knowledge about the world"

"Specifically, it has argued that immersion should be considered in terms of the amount of information about the environment conveyed to the user, and that realism should be considered in terms of user expectations for the environment."

Nunez, D.
NPR environments: How is presence in non-immersive, non-realistic virtual environments possible? [5]

Table 9: Presence quotation

The external parameters were considered in the implementation as much as the environment allowed for. Within the internal parameters, textures and realism were prioritized low while the LOD is set to decrease, when objects are positioned far away from the subject. It is attempted to exploit multimodality in order to create a coherent and stronger impression of the atmosphere. The audio is following the visualization. It is therefore of great importance that the subject obtains the impression of the two modalities being connected, which a high latency can counteract.

The implementation was tested under several conditions to measure presence through a questionnaire. It could have been interesting to test with heart rate recordings also, even though it would include wearable devices for the subject, but it was chosen not to be in the scope at this state of the project.

Following the conviction that the setup design is based on the general expected stimuli and interpreted by the subject according to one's knowledge, some variations between the subjects' gained presence feeling must be estimated. In addition, since the exploration goal is very subjective, the personal state of mind can affect the subjects' responsiveness, adaptability and acceptance of the virtual environment and its rules for exploring the setup at that particular moment.

The rest of the report is structures as follows:

Chapter 4	introduces the characteristics of the three aspects involved in the problem formulation.
Chapter 5	describes the implementation of the visualization and audio design.
Chapter 6	explains the conditions of the test setups and what the tests resulted in.
Chapter 7	analyses the results in order to discuss their validity, or the opposite, and considers enhancements of the setup
Chapter 8	concludes on the test analysis according to the problem formulation.

4 Implementation features

To create the feeling of presence, it is necessary to look into the way stimuli from different modalities are interpreted and how they either support each other or enhance one of them.

The problem formulation included following aspects, which are the considered means for this project:

- Virtual animations
- Spatialized sound
- Multimodality

They are introduced in the following three sections.

4.1 Virtual animations

Motion is a cue providing lots of information about the environment a person is situated in. It can be a navigational cue, e.g. telling whether it is possible to cross a road before a car drives by or it can show the psychological state of a person, e.g. excitement or being upset.

The function of the human eye is based on changes over time [15]. To be able to see the world, the eye needs light and as minimum one edge. But without the perceived changes in colour, object position, size, etc. it would not be possible to see anything if it was not for the eye's own forced randomized movements. When a person thinks one is holding the eyes steady focused on the same spot, the eyes are actually making tiny small jumps, which are not perceivable by the person, but essential to seeing.

Motion is connected to the knowledge of objects. People can distinguish between static and moving objects based on a general knowledge gained from one's prior situations, education, books, TV, internet, etc. Motion would be expected to appear from some objects based on this knowledge. It would be expected from other people to move in some degree. It would be expected from an area with roads, that sooner or later, cars will drive by. All these expectations are important to fulfil in a certain range in the virtual world to make the perception satisfactory enough to make a person feel present.

If the environment becomes too mechanical and create some kind of motion pattern, which are not expected from that type of moving object, a person will soon see through the illusion. Random

behaviour and appearance according to the expectations to the elements is therefore important to maintain the trust in a non physical world.

4.2 Spatialized sound

Sound is all around us, wherever we are. If the environmental sounds are not perceivable, then at least we hear our own sounds, e.g. breathing and footsteps.

Even among many sounds sources reaching the human ears at the same time, it is possible for a person to point out one specifically source. It is a modality which people expect to be present in all situations without always being aware of its presence.

The perception of being physical present in an environment is in a high degree derived from the surrounding sounds, since it is possible to hear sounds coming from around the corner but not possible the see around a corner. The sounds are used as references concerning direction and distance information of the environment. By knowledge and experience people are able to recognize and estimate locations of sound sources in some degree. Sound hits the ears from different directions with different speed and intensity. People perceive the same sources slightly different according to the shape of the ears. By turning the head the perception of the sound changes because it hits the ears from another angle and has to travel through another path to reach the ears.

Additionally, the sound characteristic is changed on the way from starting position to a person’s ears. The source will gradually be absorbed by the air and if it hits other objects on its way. Collisions create multiple echoes of the sound source, referred to as reflections. The reflections will also be absorbed and decaying, which will be perceived as reverberation. A large room maintains the reflections longer. The sound travels longer before it hits walls and obstacles and get absorbed.

4.3 Multimodality

In the physical world the human being constantly perceives stimuli from the surrounding environment. The feeling of presence is based on unconsciously perceived changes in the perceived images, in the audio that reaches the ears, in the physical connections there are between the human body and the world around. Everything that is touched, heard, seen, tasted and smelled provides the human system with information that all together makes a person aware

of many levels of the current situation, from details as material and weight to the estimation of distance and speed. Multiple processes are parallel in progress within fractions of seconds.

When a stimulus is providing physical information about the element, which the stimulus is attached to, it is called intersensory integration. A stimulus can also affect other stimuli in different ways. Intersensory interaction occurs when the stimulus from one modality is affected by another, so it is perceived according to the other stimulus and not itself. The ventriloquism effect is an example of how the puppeteer’s voice is perceived as coming from the puppet instead. In this example vision is changing the perception of audio.

It is possible to replace one modality with another by creating cues that simulates the replaced modality. E.g. hitting an object with a stick normally creates both audio feedback and a tactile feedback in the hand from the collision. The sound alone can overwrite the tactile sensation, if the cue is strong enough, hence producing a very similar experience as in physical environments. This is called intersensory substitution.

The focus of this project is to make the user feel a higher level of presence in an animated virtual space. It is intended to create a similar atmosphere as in a real indoor arena. The sounds and noises pending from audience create a higher intense situation than the images alone would produce. This way the audio is functioning as a supporting modality to the vision modality. This is called cross-modal enhancement.

5 Installation design and implementation

In order to create presence the virtual environment in this project is a future construction of an indoor multi arena which should be able to contain up to 15.000 people. Different entertainment purposes would be expected to be carried out in the arena; sports activities like tournaments of ice hockey, basketball and handball as well as music concerts and exhibitions. A handball interior was chosen as the scenario to test the installation.

The setup was designed with the intension of utilizing the implementation means, which originated from the problem formulation, in order to create a higher feeling of presence when exploring a virtual environment. The virtual animations and the spatialized audio represent a visual-audio relationship in a cross-modal enhancement.

The used equipment in the setup was borrowed by the educational institutional and set up in a laboratory on campus.

5.1 Setup

The equipment of the setup was chosen wherever possible as familiar products to benefit of the test subjects' knowledge in how to use them. They are accessible and vary in price depending on device type. The setup needs high quality computers graphic cards to process the setup. Despite the high demands the computers are considered as rentable. Likewise are the keyboard and the mouse. The audio devices, loudspeakers and audio interface, used in this project are, however, must be expected to be categorized in a higher prize range. An alternative is to use fewer speakers, which would decrease the options on the audio interface as well and possible affect the price to be less expensive.

The used software for implementing audio and visualization were

Maya 7.0 : Software for creating 3D graphics in which models and animations were developed
Virtools 4.0 : Real-time rendering software to make it possible to interact directly in 3D environments
Max/MSP 4.5 : Software for developing graphics and sounds.

The speakers were preferred in preference to headphones in order to avoid placing devices on the subject and to maintain a large degree of freedom for the subject. Having to wear a lot of equipment could create unnecessary focus on the equipment, making it more difficult to maintain a coherent experience in the virtual world.

The setup contains following equipment

A) One large screen
B) One projector
C) Eight loudspeakers
D) One audio interface
E) One computer administrating the audio
F) One computer administrating the visualization
G) One keyboard
H) One mouse

The test subject was positioned in the centre of the setup. The audio was processed through eight speakers positioned in two groups. An area around the test subject of 3,0 x 2,5 meters was predefined for the position of the speakers. One group of four speakers was placed on the floor in the corners of the area. The other group was placed at the same horizontal positions, but above the first group. All eight speakers were connected to PC1 through an audio controller, which is able to administrate all eight speakers individually. The visualization was back projected on a 2,5m x 2,5m screen, which was placed in front of the subject.

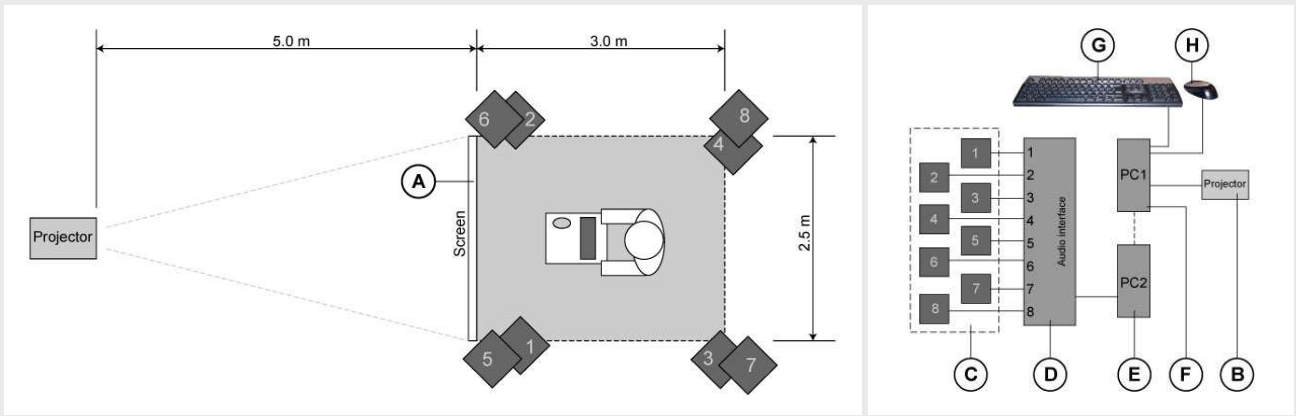


Illustration 2: Setup

Two control devices are used, which is considered not to be the most comprehensible solution. During the development of this project, the two devices integrated intuitively to some extend. For

the environment in this project, the keyboard worked acceptably. It is a familiar device, demanding no extra concentration in learning how to control it, leaving more focus on the exploration itself.

The mouse was used for activation buttons. The keyboard could have replaced these mouse actions. However, this would have force the test subject to remove the focus from the screen to the keyboard in order to find the correct keys for the actions. The mouse is better integrated as a natural extension of the hand and can be controlled without having the eyes on it. A standard computer mouse is unfortunately not suitable for controlling the navigation since it only makes it possible to scroll back and forth.

A better solution could be to implement a track-ball mouse in Virtools as the only control device. It has some nice advantages of having a larger degree of scroll freedom available while still having buttons to be used for actions. The track-ball mouse was considered in the initial state of the process. Unfortunately, it was not prioritized due to the project time limit. The keyboard and mouse are two devices well known from a personal computer to be able to work together, but it would have been more optimal to have only one device to concentrate on.

5.2 Network connections

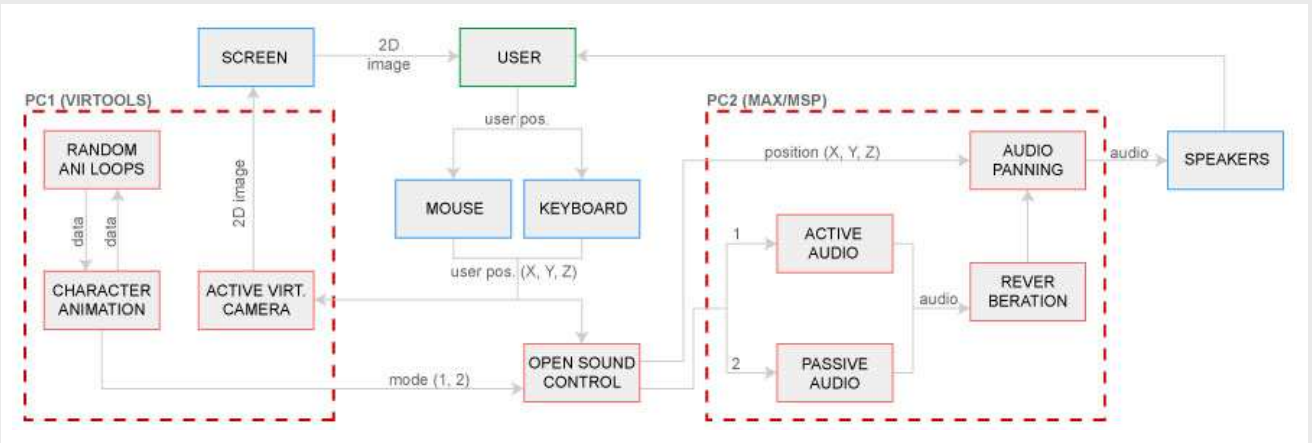


Illustration 3: Flowchart

The visualization was implemented on one computer (PC1) while the audio was implemented on second computer (PC2). To be able to send data from PC1 to PC2, Open Sound Control (OSC) was utilized. OSC is a protocol for communication data between computers, e.g. for message purposes or sound purposes. To administrate the message data between the software, it is necessary to add objects in the software [20] [21]. To create the connection different ports must be

used for different messages. Only the send-object needs to have address information to know which computer to send the data on the network.

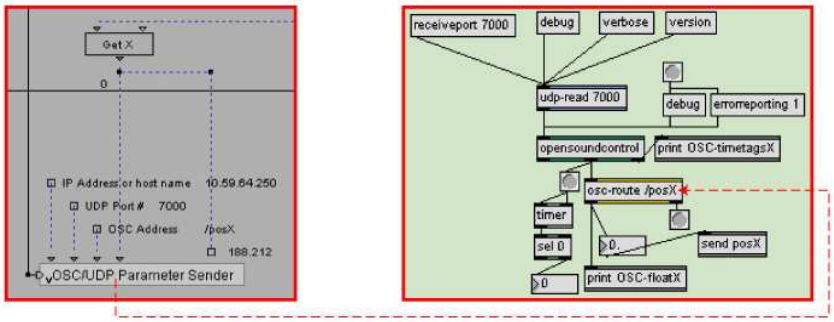


Illustration 4: Network connection

Nine parameters were sent from PC1 to PC2 (see Table 10: Network data). The choice of setup, when starting a test, controls which speakers to process the audio. Activating setup 1 will not send any information to PC2 at all making all the speakers silent. Choosing setup 2 sends a command to PC2 which only let audio be processed through speaker 1 and 2 to create stereo sound. The third setup activates audio on all eight speakers.

Network parameters	Activation	Port no.
AUDIO ON	On play CMO	7010
AUDIO OFF	On exit test	7011
POS X	On translation keys pressed	7000
POS Y	On translation keys pressed	7001
POS Z	On translation keys pressed	7002
SETUP 2 (SP1 + SP2 ON)	On setup 2	7004
SETUP 3 (ALL SPEAKERS ON)	On setup 3	7005
ACTIVE ANIMATION ON	On active animation start	7006
ACTIVE ANIMATION OFF	On passive animation on	7007

Table 10: Network data

The keyboard is connected to PC1 controlling the subject's visual field of view. The behaviour of the audio is updated according to start setup, exit and x-, y-, and z- value of the current subject position in Virtools on PC2. The three position parameters are only updated when a control key is pressed. If the map is used to shift position, the amplitude is updated accordingly to the new position.

5.3 User control

The navigational control of the setup was designed in Virtools. When starting the Virtools scene, the CMO, the duplication process of the characters to create the audience starts automatically. When the audience creation has finished, the light fades out and the setup buttons appear on the screen.

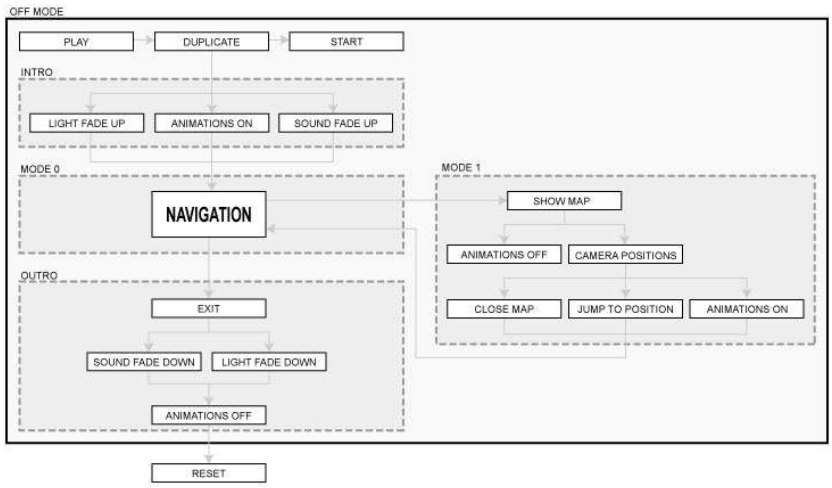


Illustration 5: Navigation

The CMO is now ready to start an exploration. When pressing on one of the setup buttons the light will fade in. Initially camera A is set as the active field of view (FOV). Navigation is possible by moving and rotating the active camera. By viewing a map, it is possible to jump to five different predefined positions (see Illustration 7: Predefined positions views). There is no information on the map about test subject's current position. This was considered, but for the tests the lack of information was perceived as an advantage. It could force the subjects to explore the environment and in this way make them more familiar with the environment and more experienced with the control devices.

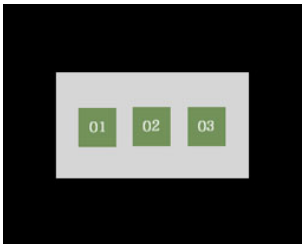
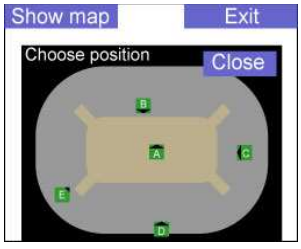
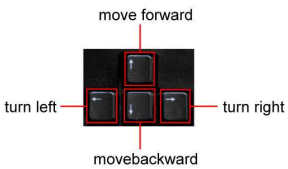
Start	Mode 0	Mode 1	Navigation
			

Illustration 6: Control

The test subject can be in two different modes. From the beginning of the exploration, the setup will be in user mode 0. In this mode, the subject can “walk” around by using the keyboard, having a large field of view. In mode 1 five predefined positions are available to the subject, which can be chosen by viewing a map over the arena. When the position has been chosen, the mode will automatically change back to mode 0, while the selected field of view will fade in from black.

Start camera	Camera A	Camera B	Camera C	Camera D	Camera E
					

Illustration 7: Predefined positions views

A camera is created in advance for each predefined position. When a predefined position has been chosen, all cameras including the current camera will be reset to its initialized position and the chosen camera will be the active FOV. All the navigational settings will now be active on the chosen camera. Next time another camera, or the same camera, is being chosen from the map, same process will be activated.

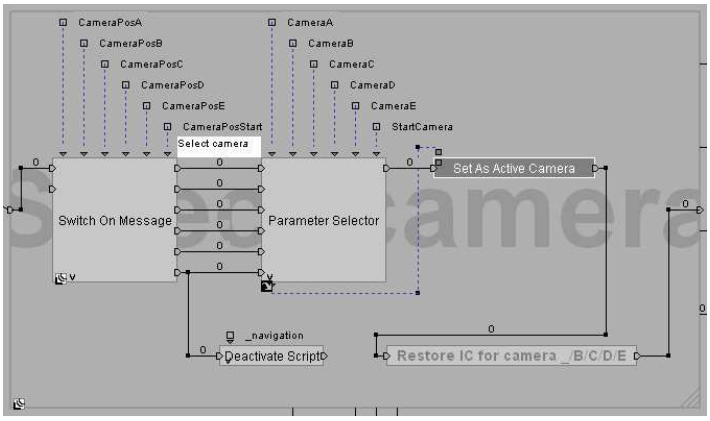


Illustration 8: Camera script

By pressing the EXIT button, the exploration will be terminated and the light will fade out together with the audio volume and the setup buttons will reappear. The setup is now ready for a new exploration.

5.4 Visualization

In Autodesk Maya 7.0 the following 3D objects were modelled:

- One arena
- Twelve characters
- Two goals
- Centre court
- Court floor
- Roof
- Audience rails

They were exported to Virtools 4.0 where buttons, text and two lights above the centre court were added. All the textures and the character materials were created in Maya and exported together with the models and characters.

No characters have been developed to be handball players. It is only the appearance of the arena together with the audience behaviour and sounds, which express that something is going on in the arena and indicate what kind of event it is.

5.4.1 Virtual environmental design

The arena is constructed to contain about 15000 people. It is created with fewer details compared to an architectural design, but still constructed with characteristics enough to make sure that it is perceived as an arena. Much of the arena is occluded by the audience and it was not necessary to make place for seats. Instead rails have been produce to define the audience areas on the staircases. To show that the scenario is a handball match, the arena contains two goals and a court floor with a texture illustrating the painted lines for this type of sports. The rest of the floor is provided a texture similar to the court but without any painted lines. Several exits are included in the arena design, but only for appearance purpose. They can not be used in the navigation. A roof is sealing the environment.

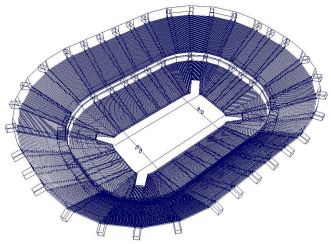


Illustration 9: Arena

Only the lower part of the arena is used, due to a very high process time demanded if audience were to fill out the upper area also.

5.4.2 Character design

The amount of people to create an audience would create many polygons to be rendered. Therefore, the characters are produced with few polygons. Many people being present at one time decrease the perception of each person. They will in some degree blend in with each other and hide many characteristics, e.g. hair, facial elements and fingers.

Characters were developed in four different heights. With each height three characters were produced with different shape of mesh. All twelve characters have unique names for groups, locator, mesh, joints and handles. The material names remains the same for all the characters.

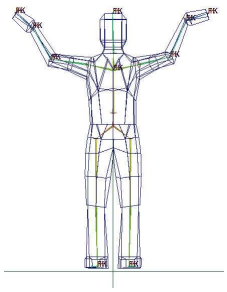
FRONT VIEW (wire frame)	FRONT VIEW (textured)	SIDE VIEW (textured)
		

Illustration 10: Character

To be able to control a character and its animation correctly in Virtools there are some export settings which are important. The characters are exported as character and with Helpers. The characters are using a Locator as the parent for mesh and joints. Exporting with Helpers makes sure the Locator keeps its function as being the parent of the character parts.

5.4.3 Character animation design

In this project the scenario has been chosen to be a handball match. It would be expected from the audience to involve themselves in the match by their respond to what is happening down on the court. In all their activities, they create perceivable motion, both small and large. All these movements make a person feel that life is all around, hence, enhancing the atmosphere. This always moving behaviour is attempted expressed by random controlled character motion.

The animations were created in Maya, each including only one cycle of movements with the intension of looping the cycles in Virtools. Seven different key-frame animations were created and used on each of the twelve characters. Three animations express the passive audience behaviour with arms lowered and primarily moving calm and slowly. Four animations were made for active behaviour. They raise their hands to clap or cheer in more aggressive expressions.

Each of the animations was exported to Virtools separately and as key-frame animations in order to remain the animation behaviour as in Maya. In Virtools, the animations were divided in two groups; the passive and the active animations. A random duration of time is selected for both the passive and the active behaviour group. When its time has run out, the active behaviour group will be activated and run for a random duration of time.

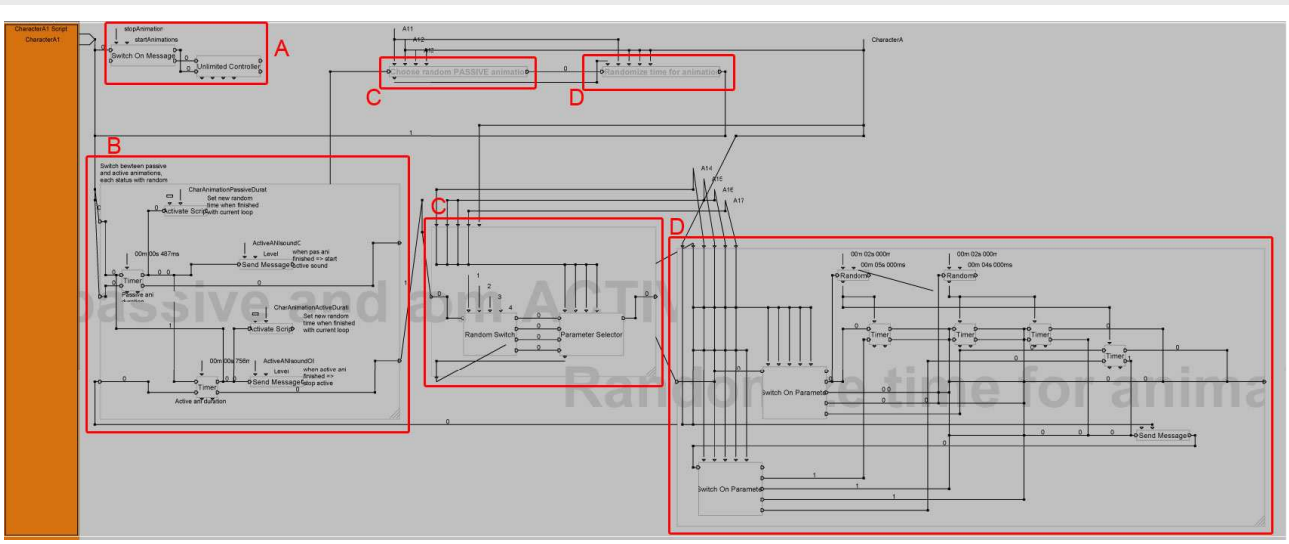


Illustration 11: Character A1 script

Illustration 11 shows the animation script for CharacterA1. A script in Virtools consists of building blocks, BB, containing functions. The connection between different blocks and their parameters controls the behaviour of the script. The messageBB (A) controls whether the animations are activated or not. Before the actual exploration of the virtual world starts, the audience is being created and at this state it is not necessary to activate the animations, which can occupy the computer processing unnecessarily. When the map is activated, the animations are equally paused.

(B) in illustration 11 describes the control of the random time duration for either passive or active behaviour. When the character script receives a message to start the script, the passive

animations are activated first. It will choose a random passive animation (C) and loop the animation in a random duration of time (D). When the animation loop is finished it activates the behaviour duration graph (B) and checks the status time for this behaviour. If it has reached the time limit, it will activate the output of the Timer building block, TimerBB, which will initialize the active behaviour process. At the same time it will create the duration time for the next time passive animations are activated. If the time limit has not been reached, the TimerBB will activate the LoopOut output and a new passive animation is randomly chosen and looped for a random time.

Illustration 12 describes the general process for the run mode of either passive or active animation behaviour.

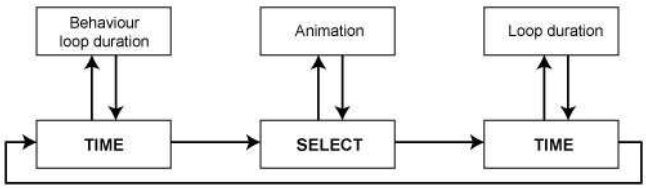


Illustration 12: Animation process

5.4.4 Creating the audience

34 grids are created as position spaces for groups of characters and placed accordingly to the rails on the audience area. Each grid has a duplication script attached. Multiple duplication scripts activated simultaneously slowed down the process too much, due to overloads of computer computations. Instead, the duplication process is controlled by connecting the grids in serial, activating only one grid's script at the time.

The script in illustration 13 shows the different factors to be preceded during one loop. On initial message (A) when starting the CMO, the first grid processes the amount of duplications necessary to reach the maximum value of the counter (B). The loop number is used as reference to which cell to extract the position from. For each loop a cell position is detected (C), a random character is chosen to be duplicated (D) and the duplication is carried out (E). Before finishing the loop the new character is given a random shirt colour (F1), added to a group (F2) and rotated (F3). When it has finished the counter activates the next grid by sending a message to its script (G).

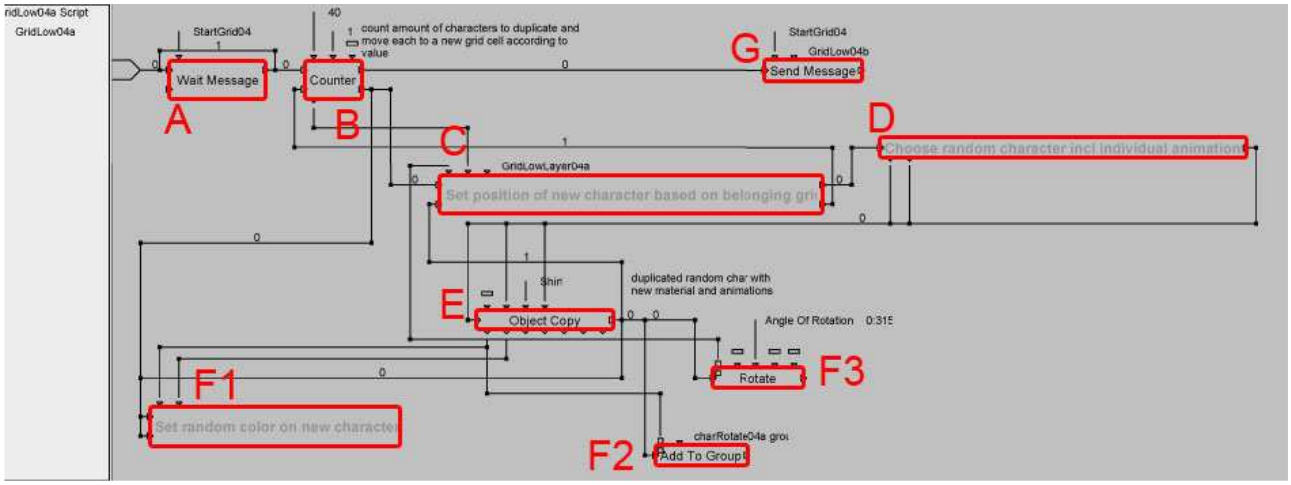


Illustration 13: Copy character

When duplicating a character, it is possible to control the copy conditions in advance. Joints, handles, animations, mesh and materials are duplicated. Each copy options are named dependently on the source character but given a unique name, based on the source name. E.g. a copy of a character called characterA1 will be named characterA1001. And 001 will be added to the other copied options; material, mesh, etc. To be able to control the animations separately for each new character, they do not share animations even though the animations are copied. The script attached to the source character is also duplicated. It contains random building blocks for many settings, so using the same script on several characters will not create synchronized behaviour.

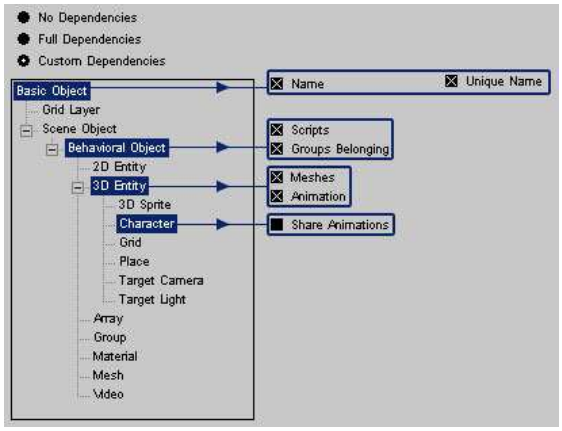


Illustration 14: Copy settings

The advantages of duplication the characters after playing the CMO are to make the source file smaller and reusing some of the parameters like material and scripts. However, it is also necessary

to calculate with an initial starting time when playing the CMO, since the duplication process can take a while. In this project 1122 characters are duplicated, positioned, given a random material colour for the shirt, added to a group and most of them rotated. It takes approximately one and a half hour before the CMO is ready to interact with.

5.4.5 Visual effects

Going from the physical world to the virtual world might demand adaptation in some degree by the test subject. There is a risk that the subject still has more focus on the physical world in the beginning of exploring the virtual world. To make the shift to the virtual environment noticeable for the subject and gradually make the subject familiar with the new conditions, the exploration starts with a short intro. It simply fades in the visualization from black. The sound volume is faded in simultaneously. When ending the exploration by pressing the button EXIT the same process is carried out in reverse order, fading the visualization out to black and fading audio to no volume, as an outro. The fading is also used when changing from one camera to another, to emphasize the change in field of view without interrupting the focus when jumping to a new position.

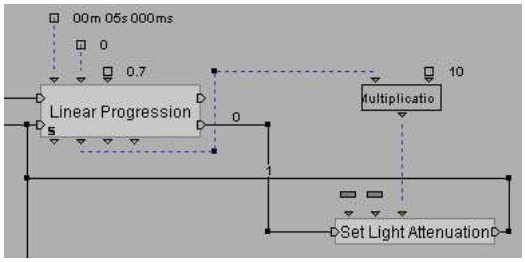


Illustration 15: Light fade

This kind of editing technique is obtained from the film industry, where fades are commonly used during a movie to tell the story. Based on the long background history within this field, film editing techniques have become commonly known and accepted by people. The expected familiarity to fades was the basis for utilizing it in this project, which might maintain their focus more on the virtual environment [5] [23].

5.5 Audio design

In the chosen scenario audio is a very strong cue to exploit. The atmosphere is created in a high degree by the sounds from the audience. The audience expresses their feelings to the match by cheering, clapping, etc. Sometimes when watching a match on the television, fully aware of not being present in the actual arena, the audience sound itself can create intensity so strong that it can affect the television viewer to shut out the physical world.

5.5.1 Audio playback

Two audio clips are used in the setup and their audio behaviour is designed in Max/MSP. One clip represents the passive behaviour of the audience and another clip expresses the active audio feedback when the characters are behaving actively. The passive and the active audio clip each have their own private patch in which the same clip is represented two and three times. Delaying the second and third version of the audio clip produces an impression of an ongoing stream of audience noises, with lower the possible audible changes between stopping and starting the clip in between loops.

5.5.2 Spatialized audio

Speakers are used to produce immersive stimuli in the setups. The sound is designed with the purpose of creating spatialized sound, expressing how sound changes amplitude and characteristics when being in motion.

Two factors were used to produce spatialized audio:

- Panning
- Reverberation

The panning technique is based on vector based amplitude panning (VBAP) approach. It is efficient in using several speakers in a setup to simulate sound source positions and it is not restricted to a 2D setup, it works with elevation cues, too (see Illustration 17: 3D panning) [11].

A Max/MSP patch has been developed to implement the VBAP technique (see) [11]. The object consists of three objects (see Illustration 16: VBAP objects)

- Defining loudspeakers
- VBAP
- Matrix~

In the object “Defining loudspeakers” the directions of the loudspeakers in the setup are defined and the dimension of the setup is declared by writing either 2 or 3. If the setup is in 2D then the azimuth angles are written according to the centre position in the setup. If a 3D setup is defined then the direction for each speaker’s azimuth and elevation angle are written in pairs just separated by a space, e.g. azi1 ele1 azi2 ele2.

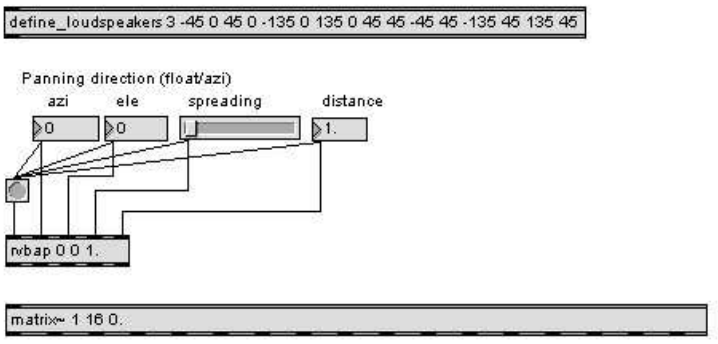
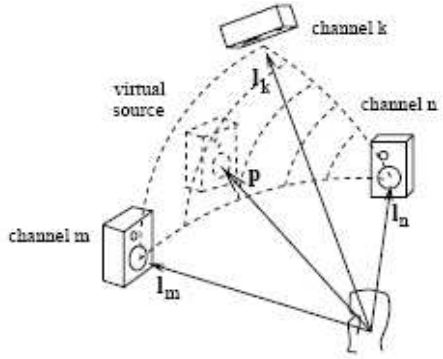


Illustration 16: VBAP objects



[11]

Illustration 17: 3D panning

The VBAP object controls the spreading and direction of the sound source. The latter creates a sound source as having the specified direction according the azimuth and elevation angles. The spreading creates more than one sound source vector in close spaced angles to the original vector. The value can differ between 0 and 100, where 100 create many sound vectors.

In this project it was not necessary to produce a specific direction of the sound source since the source contains various sounds to produce the impression of having many people in the same location, hence, the azimuth and elevation angles remain 0. The spreading parameter is also set to 0 in order to make use of ordinary amplitude panning expressed in only one source vector. Due to the many different sounds within the sound sources themselves, the individual audio panning might be lost if using the spreading parameter.

The matrix~ object takes all input sound sources and sends them to all outputs by multiplying with the gain factor from the VBAP object.

Reverberation and localizing sounds in a three wall projected CAVE utilizing speakers has showed positive results in a project performed in 2002 [8]. The CAVE project also supports this project's view on wearing a minimum of devices, in order to provide the test subject with a large degree of freedom, on which the decision on using speakers and not headphones was made.

Reverberation expresses the characteristics of the room, if it is a big or small place. In the patch with the VBAP object a reverberation object (monoverb~) is added for each signal output from the matrix~ [22]. Each monoverb~ takes the output signal from the matrix~ and creates a reverberated signal which is then summed with the original unreverberated output from the matrix~ in the delay

patcher. In the delay patcher two objects are used called tapin~ and tapout~ for each signal, which is a simple way to secure that the signals are send to each of the eight speaker simultaneously.

The reverberation can be set to a value between 0 and 1. If the value is very high it can be difficult to maintain the reverberation effect and begin to perceive the delayed signals as echo and not reflections. This courses a distorted sound, which changes its characteristics to be more metallic like. The reverberation value is set to be 0.4, which produces spatial perceived sound without distortion.

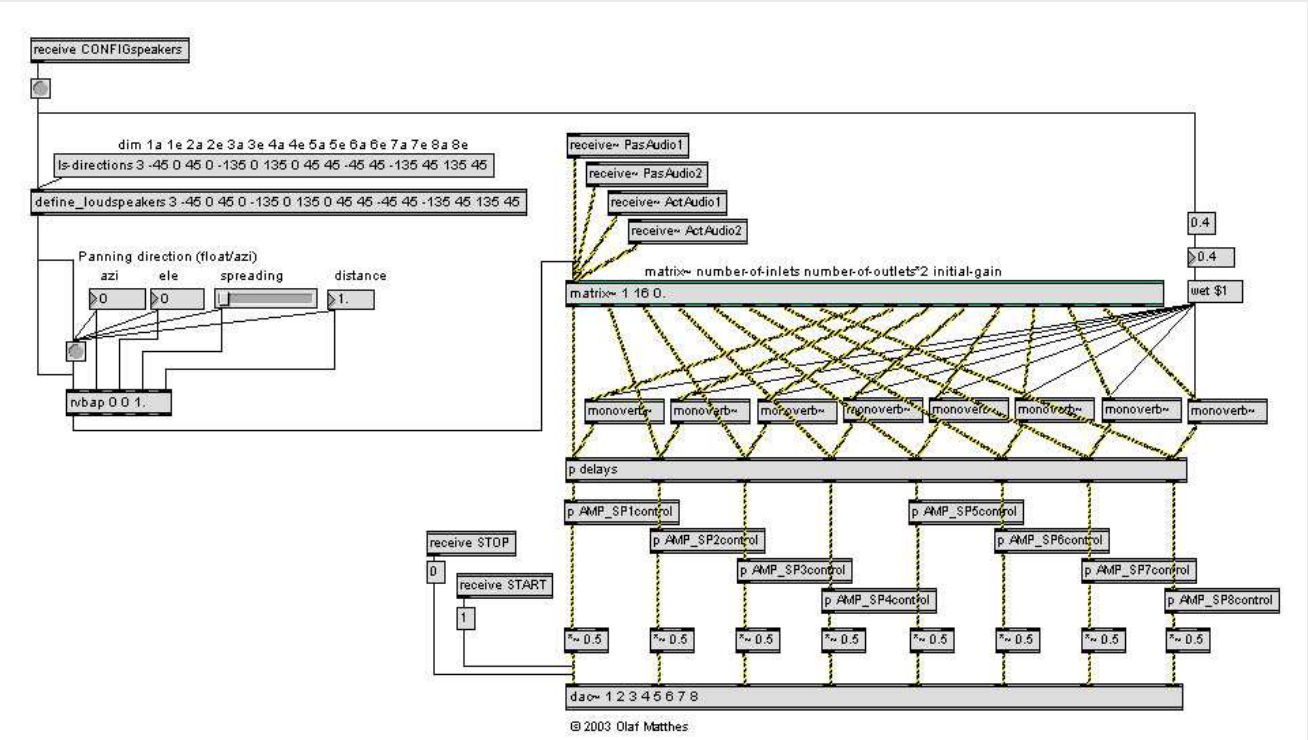


Illustration 18: Panning and reverberation control

The starting position (0,0,0) in Virtools is in the centre of the arena down on the floor. For better control of the amplitude values in order to avoid calculating with negative values, the position is shifted from the beginning of the patch in Max/MSP to have the starting position (0,0,0) in the lower left corner when the arena is seen from above with the screen placed above the arena area.

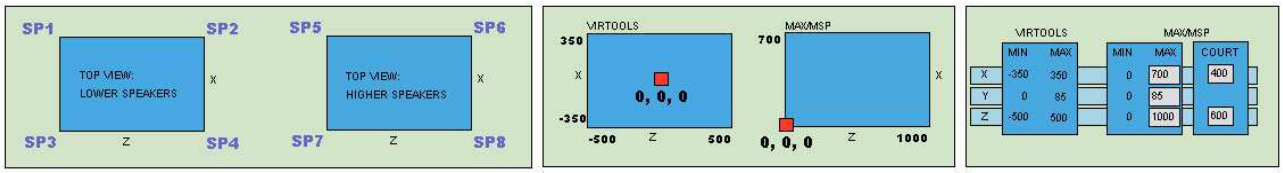


Illustration 19 Position from Virtools to Max/MSP

The upper and lower physical loudspeakers are positioned with equal distance to the user. To express the audience on the lowest horizontal plane being closer to the centre court, based on the arena appearance, the length (z) and the depth (x) value is smaller on the floor than on the highest horizontal level.

In addition to the VBAP technique amplitude panning is created based on Cartesian coordinates. For each speaker the amplitude is calculated to have the maximum amplitude when the subject's virtual position is close to the specific speaker. Moving away from the speaker will decrease its amplitude while the other speakers' amplitude increases depending on the distance to the subject and their upper or lower level units.

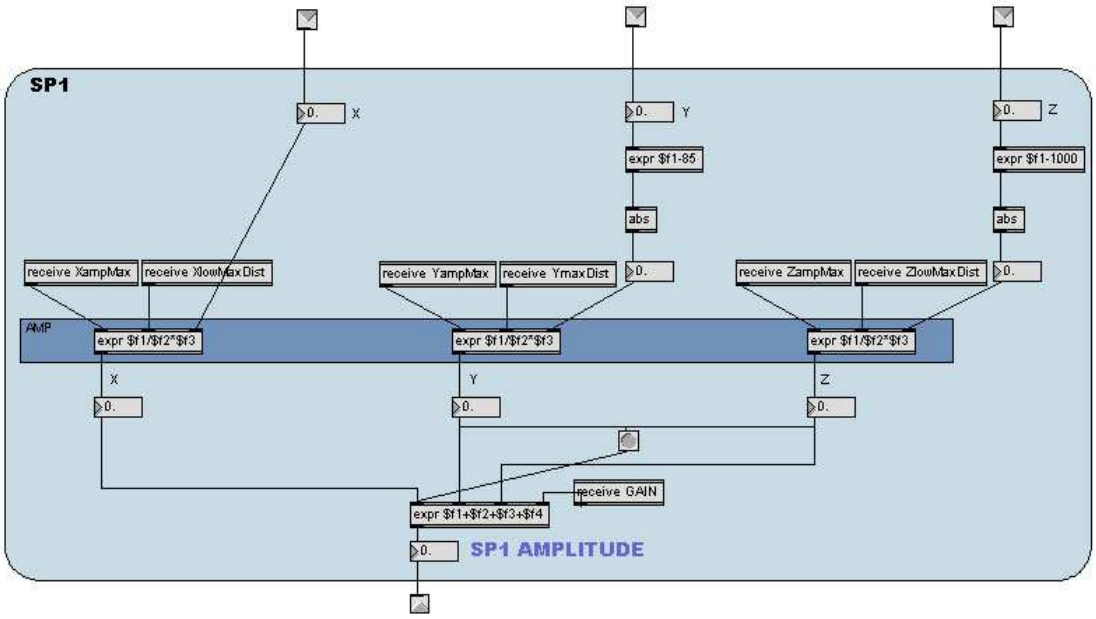


Illustration 20: Speaker 1 amplitude control

To know how much the amplitude is scaled up or down, the length (z) and the depth (x) of the lowest and the highest horizontal level is utilized to produce individual level units going from 0 to 1, which is the range of the amplitude. The distance between the lower and the upper level is used in order to get units between 0 and 1 when changing the y-value of the position.

The visualization is faded in and out from a black screen. To create coherence between the visualization and the audio, the audio is faded in and out from zero as well.

The stimuli affecting the visual and the auditory modality in the fade in and out are meant as a smooth transition when either switching between the physical world and the virtual environment or jumping from one position to another within the virtual world.

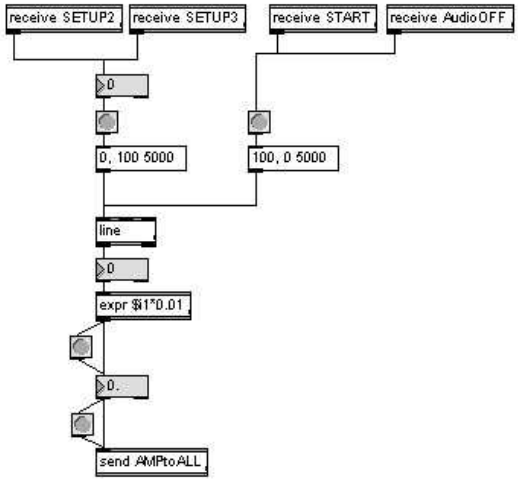


Illustration 21: Audio fade

6 Testing the setups

Three aspects were considered, to develop an immersive visualization of a future constructions project:

- Virtual animations
- Spatialized sound
- Multimodality

The problem formulation is looking for an answer to in what degree presence can be evoked compared to the normal conditions in this field, which typically do not include animations and spatialized audio.

Twelve subjects completed the test. Four subjects per setup (see table 11).

	No sound	Stereo sound	Surround sound
Mono vision	Group 1	Group 3	Group 4

Table 11: Test setups

A task was presented for all groups. The subjects were tested with different settings for the sound, while the visual representation remained mono in all tests. The results from the setup with no sound were used as reference to analyse the results from the two groups with either two or eight active speakers.

6.1 Questionnaire

The chosen questions in the presence questionnaire are developed by Witmer and Singer [14]. The questions are well expressed without being too leading and this project share their perspectives on presence being individual and subjective in a very high degree. The main aspects which they find important for presence are involvement, focus and immersion. But according to the coherence between these factors presence is gained in different levels.

The Witmer and Singer questions are associated to four groups of factors which can affect involvement, focus and immersion to create presence [14]

- Control factors (CF)
- Sensory factors (SF)

- Distraction factors (DF)
- Realism factors (DF)

These factors approach presence from different perspectives. Additional the sub factor Involved/Control is describing one of the questions, which is concerning involvement, control and interaction.

Control factors include the factors which can enhance or decrease the sense of being in control, e.g. latency, inconsistency between stimuli from different modalities, interactivity or lack of control over elements in the virtual environment.

Sensory factors concerns the factors which affect the modalities like present types of stimuli, amount of stimuli, expression of the stimuli, the coherence between the stimuli, detection of the subject's own movements and detection of the environment moving according to the subject's field of view

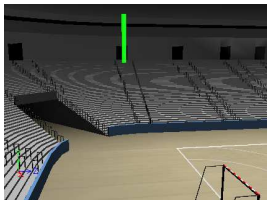
Distraction factors are whether the subject is isolated from the physical world, whether the subject can stay focused on the virtual environment despite the physical world affecting the virtual conditions and whether the subject is distracted by interface devices.

Realism factors are about the quality and impression of the virtual environment according to the knowledge, associations and expectations to the specific scenario, a developing meaningful experience and the effect of shifting back to the physical world afterwards.

6.2 Task

To make sure the tests were completed under similar conditions for all test subjects, they were all asked to perform the same task.

Five cylinders were positioned in the virtual world on different locations, not equivalent to the camera positions. The task was to navigate to the objects one by one. When the subject was close to the object it disappeared and the next cylinder appeared at another location in the arena. They had to navigate to four green cylinders and one red cylinder. The red object indicated that it was the last object to make disappear.



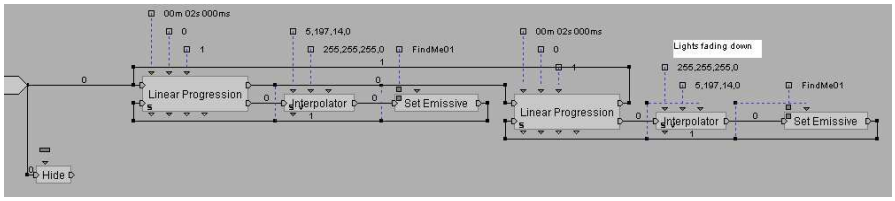


Illustration 22: Find object script

Since the subject did not know in advance where to find the objects they were forced to search around until the task was completed. With this in mind, it was expected that the subjects maintain focus on the virtual environment, in a higher degree. Focus is one of the aspects that Witmer and Singer found important in their presence research [14].

In the search of the objects the task could create a higher tendency among the subjects to be involved. This is another factor which Witmer and Singer has found important in order to produce a higher presence feeling [14].

The risk in giving the test subjects a task is, however, that they might focus too much on the task and less on the stimuli, which are supposed to affect them to feel more connected to the virtual world and hopefully create more presence.

6.3 Test description

First, the test subject was asked to fill in the first part of the questionnaire concerning personal data. Afterwards the subject chooses a setup type randomly by picking a piece of paper with the setup number written on the back. The next subject would have only two setups to choose between and the third would not have the option to choose. The fourth test subject would start over with having all three setups to choose randomly between. This procedure was used simply to make the connection between subject and setup more casual.

After the setup was chosen, the subject was guided to the position in front the setup. Then the scenario of the virtual environment was described, the task was explained and the navigational option in the environment was informed.

The subject was told to press the button with the chosen setup number and the test began. When the task was completed, the subject was told to press the exit button to end the test. Finally, the subjects filled in the second part of the questionnaire concerning the test.

6.4 Results

Twelve people completed the test, which only provide test data for four subjects per setup. This amount of subjects produces results, which can not be considered as completely reliable. However, they can indicate if the setups are going in the correct directions.

The subjects are tested under three different conditions; no sound, stereo sound and spatialized sound, which is a within subjects design. The results from the three setups are analyzed by using One Way Analysis of Variance (ANOVA). A t-test of the result data is performed by using the software R-package, which is designed for statistical purposes [24]. The Alpha-level is the threshold which separates the significant different results from the not significant different results, the former resulting in a P-value < Alpha level and the latter resulting in a P-value > Alpha-level. A common value for the Alpha-level is 0,05, which this project has used as well.

The conditions to be research in this project in order to find out if presence is enhanced are visualization added virtual animations, spatialized audio and a cross-modal enhancement through the visual and the auditory modalities. Presence is a very subjective feeling and difficult to measure. Based on that assumption the results should be considered as tendencies and not exact measurements.

	The subjects in setup 3 responded significant better than subjects in setup 2
	The subjects in setup 3 responded better than subjects in setup 2 but not significantly
	The subjects in setup 2 responded better than subjects in setup 3 but not significant
	The subjects in setup 2 responded significant better than subjects in setup 3
	The subjects in both setup 2 and 3 responded significantly equally well
	The subjects in both setup 2 and 3 to responded equally well but not significantly

Table 12: Colour explanation for table XX

The t-test results are described in table 13 according to the Alpha-level. The colours express how well the subjects in the setup 2 and setup 3 performed compared to each other.

Quest. no.	Pres. factor	Setup t-test	P-value	Null hyp.	Description
1	CF	1 - 2	0.1759	True	Subjects in setup 3 found the interactions significantly more natural than subjects in setup 2
		1 - 3	0.00524	False	
2	SF	1 - 2	0.06628	True	Subjects in setup 3 felt significantly more that all their senses were engaged significantly than in setup2
		1 - 3	0.005986	False	

3	SF	1 - 2	0.7908	True	Subjects in setup 3 were more involved by the visual environment than subjects in setup 2 but not significantly
		1 - 3	0.3896	True	
4	SF	1 - 2	0.078	True	The subjects in setup 2 and setup 3 were equally involved significantly by the auditory aspects
		1 - 3	0..078	True	
5	CF	1 - 2	0.7506	True	Subjects in setup 2 felt the movement control mechanism more natural than subjects in setup 3 but not significantly
		1 - 3	1	True	
6	SF	1 - 2	0.7921	True	Subjects in setup3 were more aware of the real world events than subjects in setup 2 but not significantly
		1 - 3	0.3203	True	
7	SF	1 - 2	0.1475	True	Subjects in setup 2 were more aware of the display and control devices than subjects in setup 3 but not significantly
		1 - 3	0.7368	True	
8	RF	1 - 2	0.1340	True	Subjects in setup 2 and setup 3 felt equally inconsistency in the information coming from the senses but not significantly
		1 - 3	0.1340	True	
9	CF, RF	1 - 2	0.7671	True	Subjects in setup 3 found the experience more consistent with the real-world experiences than subjects in setup 2 but not significantly
		1 - 3	0.1294	True	
10	CF, SF, RF	1 - 2	0.7368	True	Subjects in setup 2 were able to actively survey or search the environment more than subjects in setup 3 but not significantly
		1 - 3	1	True	
11	RF	1 - 2	0.078	True	Subjects in setup 2 could identify sounds more than subjects in setup 3 but not significantly
		1 - 3	NULL	True	
12	RF	1 - 2	0.11621	True	Subjects in setup 3 could localize sound significantly better than subjects in setup 2
		1 - 3	0.01822	False	
13	SF, RF	1 - 2	0.3896	True	Subjects in setup 3 felt the sense of moving around inside the virtual environment more compelling than subjects in setup 2 but not significantly
		1 - 3	0.3203	True	
14	INV, C	1 - 2	0.01747	False	Subjects in setup 2 was significant more involved than subjects in setup 3
		1 - 3	0.2277	True	
15	SF	1 - 2	0.418	True	Subjects in setup 2 was more distracted by the control mechanism than subjects in setup 3 but not significantly
		1 - 3	0.7567	True	
16	CF	1 - 2	0.3179	True	Subjects in setup 2 experienced more delay than subjects in setup 3 but not significantly
		1 - 3	0.7718	True	
17	CF	1 - 2	0.391	True	Subjects in setup 2 and setup 3 adjusted equally quickly but not significantly
		1 - 3	0.391	True	
18	CF	1 - 2	0.1294	True	Subjects in setup 2 felt a little better in moving and interacting than subjects in setup 3 but not significantly
		1 - 3	0.2978	True	
19	SF	1 - 2	0.1633	True	Subjects in setup 2 were more distracted by the visual display quality than subjects in setup 3 but not significantly
		1 - 3	1	True	
20	DF, CF	1 - 2	0.8354	True	Subjects in setup 3 felt the control devices interfered more with the performance of the task than subjects in setup 2 but not significantly
		1 - 3	0.1060	True	
21	DF	1 - 2	0.671	True	Subjects in setup 2 could concentrate on the task rather than on the control mechanism a little better than subjects in setup 3 but not significantly
		1 - 3	0.7809	True	

Table 13: Test groups

It should be considered if a difference is positive or negative according to the question. If the question is asking about a factor being good, then a significant difference is positive, but if it is about a factor being poor for the experience, a significant difference is negative for the result.

To support the T-tests, the direct answers are evaluated (see table 18). For each question the average of the subjects in the same setup was calculated.

Question	No	Stereo	Spatial
1) How natural did your interactions with the environment seem?	1,75	3	3,25
2) How completely were all of your senses engaged?	2	4	3,75
3) How much did the visual aspects of the environment involve you?	3,5	3,75	4,25
4) How much did the auditory aspects of the environment involve you?	1	3,25	3,25
5) How natural was the mechanism which controlled movement through the environment?	2	1,75	2
6) How aware were you of events occurring in the real world around you?	2,5	2,25	1,75
7) How aware were you of your display and control devices?	3,5	4,75	3,75
8) How inconsistent or disconnected was the information coming from your various senses?	2,25	4	2
9) How much did your experiences in the virtual environment seem consistent with your real-world experiences?	2,25	2,5	3,25
10) How completely were you able to actively survey or search the environment using vision?	3,75	3,5	3,75
11) How well could you identify sounds?	1	3,25	5
12) How well could you localize sounds?	1	3	3,25
13) How compelling was your sense of moving around inside the virtual environment?	2,75	3,5	3,5
14) How involved were you in the virtual environment experience?	2,5	3,75	3,5
15) How distracting was the control mechanism?	3	3,75	3,25
16) How much delay did you experience between your actions and expected outcomes?	2,25	3,5	2,5
17) How quickly did you adjust to the virtual environment experience?	4	3,5	4,5
18) How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	4,75	3,75	4
19) How much did the visual display quality interfere or distract you from performing assigned tasks?	1,5	3	1,5
20) How much did the control devices interfere with the performance of assigned tasks?	3,5	3,75	2
21) How well could you concentrate on the assigned tasks rather than on the mechanisms used to perform those tasks?	4	3,5	4,25

Table 14: Average setup results

7 Discussion

7.1 Results with significant difference

Question 1, 2, 11 and 12 are the only answers with a P-value below the Alpha-level, however, only for setup 3; not setup 2 (see table 14). The answers to question 2 and 3 indicate that the subjects' connection were good and integrated the senses well in setup 3. Question 11 and 12 both concerns sound which can be considered to have a good effect on the subjects' experience. Since it was only setup 3 which produced significant different results, the spatialized sound apparently have a more positive effect on these four factors.

Question	Setup 3 effect
1) How natural did your interactions with the environment seem?	POS (CF)
2) How completely were all of your senses engaged?	POS (SF)
11) How well could you identify sounds?	POS (RF)
12) How well could you localize sounds?	POS (RF)

Table 15: Questions where setup 3 is closer to the Alpha-level

The results from question 12 and question 13 are consistent with the assumption of spatialized sound being more realistic than stereo sound.

7.2 Setup 2 versus setup 3

Four subjects per setup were tested, which did not produce enough data to make the results totally reliable. Even though only few questions resulted in a significant difference, comparing the results between setup 2 and setup 3 might show if spatialized sound is better for the exploration than stereo sound.

Table 13 shows the P-values for setup 2 and setup 3 compared to the Alpha level.

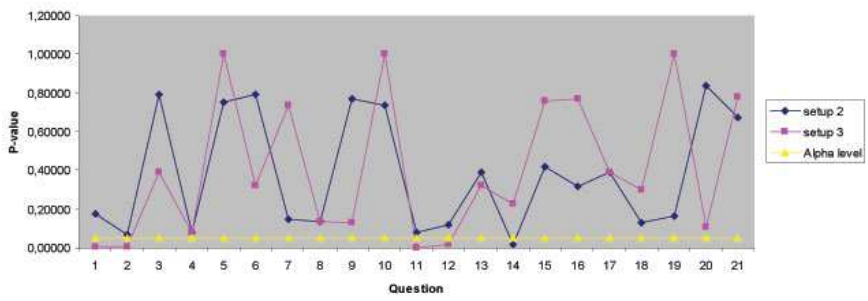


Table 16: P-values for setup 2 and setup 3

Setup 3 was closer to the Alpha-level than setup 2 in question 3, 6, 9, 13 and 20 (see table 16).

Question	Setup 3 effect
3) How much did the visual aspects of the environment involve you?	POS (SF)
6) How aware were you of events occurring in the real world around you?	NEG (CF)
9) How much did your experiences in the virtual environment seem consistent with your real-world experiences?	POS (CF, RF)
13) How compelling was your sense of moving around inside the virtual environment?	POS (SF)
20) How much did the control devices interfere with the performance of assigned tasks?	NEG (DF, CF)

Table 17: Questions where setup 3 is closer to the Alpha-level

Setup 3 was more distant to the Alpha-level than setup 2 in question 5, 7, 10, 14, 15, 16, 18, 19 and 21(see table 17).

Question	Setup 3 effect
5) How natural was the mechanism which controlled movement through the environment?	NEG (CF)
7) How aware were you of your display and control devices?	POS (SF)
10) How completely were you able to actively survey or search the environment using vision?	NEG (CF)
14) How involved were you in the virtual environment experience?	NEG (INV/C)
15) How distracting was the control mechanism?	POS (SF)
16) How much delay did you experience between your actions and expected outcomes?	POS (CF)
18) How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	NEG (CF)
19) How much did the visual display quality interfere or distract you from performing assigned tasks?	POS (SF)
21) How well could you concentrate on the assigned tasks rather than on the mechanisms used to perform those tasks?	NEG (DF)

Table 18: Questions where setup 2 is closer to the Alpha-level

Setup 3 created better factors in seven questions compare to setup 2, which is only one positive answered question more than setup 2. Apparently the two audio setups produced an almost equally well experience. Looking into the positive conditions for the two setups, setup 3 is primarily concerning sensory factors, which indicate coherence between the stimuli from visual and the auditory modality and describes how the stimuli affected the subjects positively. This inclination describes that multimodality is present in a cross-modal enhancement. The control factors are represented very little in setup 3, which could be coursed by a low interaction level based on the keyboard delays in the navigation.

The factors negative for setup 3 is positive for setup 2 in table 16 and table 17. The main positive factors present in setup 2 are the control factors. Apparently, the subjects were less distracted by the control devices and the physical environment, they felt more comfortable using the control devices and they were more able to search the environment using vision than subjects in setup 3. In addition, the sensory factors were decreased in setup 2. It is possible that the coherence between the modalities were interrupted by the slow control device, which led to the degraded presence of sensory factors.

The obvious aspect down scaling the setup results is the slow update rate when navigating with the keyboard. If the setup were improved to make the control devices perform more efficient, the control factors might be more visible in setup 3 and enhance the presence feeling together with the sensory factors.

7.3 Evaluating the setup values

The answers in question 1 decrease nicely from setup 1 to 3 indicating a higher natural interaction level the more auditory stimuli the subjects got.

Question 2 do not have the same continuing increments but show a visible difference in setup 2 and 3 compared to setup 1 concerning having the senses engages.

Question 3 shows a high involvement in the visual aspects the more auditory stimuli are added to the setup, indicating that the visualization was improved most with spatialized audio. Question 19 supports the positive impression of the visualization to some degree, because the answers to whether the visual display distracted the task, or not, for setup 1 and 3 are fairly low, but the average answer for setup 2 is scaled up twice the size of setup 1 or 3.

In question 4 the subjects are very much affected by having sound compared to setup 1, but no difference was produced between setup 2 and 3, which cannot tell whether spatialized is improving the involvement.

Despite a higher involvement (Q3) and a more natural interaction (Q1), the answers in question 5 show that the control devices did not become a natural part of the performances.

In question 6 did the subjects in all three setup once again agree in their answer. However, this question makes a low answer positive and they express that the subject were not much aware of the surrounding events.

Unfortunately, question 7 shows that the subjects were very much aware of the control devices and the screen. The answer, though, do not show a visible pattern between the setups to indicate a tendency for this question. The same setup inconsistence is applied to question 8 and 16, concerning inconsistency and action delay.

Question 9 expresses a small increase per setup, from 1 to 3, concerning consistency to real-world experiences. This can describe how the environments appearance and behaviour fulfilled much of the subjects' expectations to the environment.

Again, in question 10, the subjects agreed in their answers. In all three setups the subjects were able to survey the environment by using vision in a high degree. The audio was not designed to interact with the subject. Hence, audio is not used as a cue to navigate after and does not affect the exploration.

In question 11 concerning identifying sounds the answers show a very clear enhancement by adding sound.

Localizing sound in question 12 also has increasing answers the more sound is added, but not as clear as when identifying sounds.

The subject did not seem overwhelmed by the navigation in question 13, which might be coursed by the unfortunate slow keyboard control.

The involvement in question 14 is not very clear, either. All subjects were very similar in their answers and the answers were close to average.

It becomes clear that the control devices interfered with the experience from the answers in question 15 concerning distractions from the control mechanism and in question 20, the latter, however shows improvements in setup 3, indicating that spatialized sound might decrease the interferences.

The subjects quickly adapted to the virtual environment according to them self. They all responded with high answers in the setups in question 17.

In addition to question 17, question 18 can be evaluated. The latter showed how all subjects felt much trained at the end of the test.

Question 21 shows that the task was not difficult and the subjects had no problem in focusing on the task. But being absorbed a lot in the task might turn down the ability of integrating with the virtual environment in order to feel present.

7.4 Test observations

General observation from the tests are that the navigation keys were too slow and the navigation lacking moving and turning with a larger degree of freedom, e.g. turning up and down, moving sideways. Creating audience for an arena demands several characters to fill up the audience area to make it appear crowded. Even though only the lower part of the arena is used, approximately 1000 characters are created. All of them are animated and needed some processing power to keep them updated. The size of the crowd did not seem to have a negative effect on updating the projected images on the screen. However, as noticed by the test subjects, it affected the control keys by producing detectable latency, making the exploration very slow, specifically in the outer areas of the area, when being very close to the arena wall.

Another general characteristic of the subjects' reaction to the virtual environment was insecurity in the beginning of the test, while they had not yet seen the object to be found, despite the known information of the object's distinguished appearance. This shows how important visual cues are for a person. After the first visual contact with the task object, they were much more confident on finding the next object.

Some subjects found the visualization realistic. One subject though the crowd was cheering when the subject was moving in the correct direction towards the task object. Another felt provoked by the cheering when it happened while the subject could not find the task object. Both reactions indicate that the subjects were very aware of the sound from the crowd in a natural way. Some subjects were very familiar with computer games, which actual resulted both positively and negatively. For a couple of these subjects, they were distracted by the slow movement in a very high degree and felt very annoyed. Another subject with high skills in computer games was very efficient and completed the test as one of the fastest subjects, despite the slow navigation.

The observation of the subjects resulted in noticing different characteristics of their navigation and use of the map. Either they used the map a lot to find a faster way to get to the task object, most likely due to the slow keyboard navigation, or they hardly used the map at all. The people using the map a lot adapted to the environment and learnt its set of rules fast by using the map several times repeatedly. If they did not find the object in the first try, they used to logic to figure out which other predefined position they could use instead to jump closer to the object. Typically, they were the subjects completing the test the fastest.

The subjects, who made less use of the map, sometimes got a little confused whether to use the mouse to other actions than pressing the map button. Some subjects tried to use the mouse to click on the task object in the hope of being able to jump to it or make it disappear to solve the task in that way. The information concerning how to make the task object disappear was in these moments forgotten. This reaction to solving the task could indicate a high degree of involvement, which made it more difficult to be distracted from the physical world and kept the experience more coherent.

Shifting back to the keyboard did not always come natural for subjects using the map less, indicating that the subjects did not feel the control devices being a natural part of the navigation. This could be a result of less experience in using and get used to the map. The shifting back and forth between the two devices during the test became less trained. This observation was a surprise, since all the subjects were accustomed in using a personal computer before performing the test, in which scenario the shifting between keyboard and mouse is very familiar and practised. And the intention in this project was to make use of the known control devices in order to have fewer new rules to be learnt. It may indicate that shifting from the familiar workstation to the new scenario automatically changes the subjects' expectations of how to use the control devices. They actual expect to perform under different conditions instead of making use of their already gained knowledge.

7.5 Test evaluation and improvements

The quantity of test subjects did not achieve obvious results. But the choice of test subjects were luckily very different and only few had prior experience with virtual environments and did not have relations to this area through their occupation. This was positive, because if all of the subjects had a degree of experience with other virtual environments from e.g. computer games, their associations might force them to focus on game expectations and compare the completed test with a game when filling in the questionnaire, which was not the intension of this product.

Concluding on the observations and the test results, following setup factors should be considered revised and extended:

- Increasing the keyboard movement steps
- Increasing the keyboard rotation steps
- Increasing the degree of freedom of the field of view
- Adding a pre-test to make the subjects familiar with the virtual environment
- Adding a pre-visualization of the task object to make the subjects know what to look for

- Adding subject controlled visual and audio feedback according to the task
- Change the task to be more coherent with scenario to create a closer relationship between subject and virtual environment through the task

8 Conclusion

Measuring a subjective feeling as presence is, seems to some degree to be a very intangible concept and continuing working with this field will probably not change that perception. However, this is at the same time an exciting challenge to try and capture a feeling through tests, measurements and observations. The idea of comprehending why a human being reacts to some stimuli connections instead of others is also an attempt of understanding the nature of one self. Why is the presence feeling in some conditions easily stimulate and other times very difficult to evoke?

The aspects used in this project to evoke a higher level of presence in a visualization was

- Virtual animations
- Spatialized sound
- Multimodality

Motion and spatialized audio are factors normally integrated in a person's everyday life. People respond to motion in the surrounding environment intuitively and what can not be seen is perceived through the auditory modality, in very rich sounds informing of direction, connection and distance.

If it is possible to produce similar cues in the virtual environment, then there is a possibility of creating a higher feeling of presence. The implementation succeeded in creating random virtual animations and the audio design is utilizing 3D panning and reverberation to create sounds perceived as spatialized. The audio is controlled by the virtual animations, creating coherence between the two modalities.

The setup was tested on twelve subjects. Most of them had various backgrounds, where virtual environments are not commonly used.

The amounts of test subject were unfortunately not sufficient in order to produce reliable result data. However, the results actually did describe some preferences for the setups.

Three main observations can be extracted from the test results

- Audio is a very strong cue in itself. Two out of four results, which were significant positively different, were sound related.
- Control factors are strong, which the result for setup 2 describes.

- Sensorial factors are strong cues, which setup 3's results represented

Because of the fairly little amount of test subjects the results from the T-tests were not as clear as they would be with more test subjects. To support the T-test evaluation, the raw values for each answer were included in the analysis. The average of each setup for each question was compared.

- Question 3 showed a nice increasing process from setup 1 to setup 2 and 3 concerning the subjects being positive affected of the visual design
- Question 7 expressed the over all need for optimizing the control devices to update the navigation faster
- Question 20 supported the observation in question 7 concerning slow control devices. At the same time it produced a positive result of setup 3 in which the answer values had decreased. Considering that the only changing parameter is the audio, it could indicate that spatialized audio do affect the subject to feel more presence.
- In general, the visual and the auditory aspects affected the subjects positively. However, the control interface delay was a problem which affected the subjects' ability to carry out the task without being interrupted by the control devices, making it difficult for the subjects to maintain focus on the virtual environment.

The result did come up with results expressing the project being able to create presence under different conditions, yet it did not provide a well defined picture of its potential. More development is needed to obtain clear results. Also, it must be considered that the subjects' individual state of mind affects the results to be less uniform, due to individual preferences when performing the test concerning prior knowledge, associations and expectations. These are all unpredictable factors, making the demands to the setup more complex.

9 Project evaluation

Presence is typically used in games and experimental installation designs. It could be interesting to utilize some of these presence parameters in the industrial area and see if this area is appropriate for virtual environments including more than just stationary 3D models. Why restrict the virtual possibilities to higher research and entertainment purposes if there is a possibility of increasing the influence? This could create more development within the area through competition as well as collaborations between different specialist fields, adding new dimensions to the virtual area.

With this project it was intended to examine virtual animations in collaboration with spatialized sound in order to creating a higher level of presence in a visualization projects for the industrial field.

The animated virtual environment worked to a certain extend very well as well did the spatialized audio. The slow navigation settings unfortunately affected performance, involvement and immersion to a degree which made the results less reliable.

In addition, the amounts of test subject were not sufficient to produce reliable data, either.

Status on the setup right now is as follows:

- Patch to speaker problem with two speakers. The patch does not produce sound to speaker 5 and 7. The tests were carried out despite this error because the audio for this project did not concern exact localization of sound sources but the feeling of having sound around one, which changes in amplitude to express the position of the subject in the arena. The setup, of course would be improved when having all eight speakers producing sound.
- More tests must be carried out in order to get a better view on enhancements to improve the presence feeling
- The task in the setup should be altered to include audio feedback, e.g. make it play a song which will stop when making it disappear.
- Speed up the movements and the rotations with the keyboard.

Another important factor for a person feeling involved in a virtual environment is interactions. Visual and auditory feedback is expected under physical conditions. Integrating the subject to be able to manipulate or affect the virtual environment according to the subject’s own input, e.g. tracked

movements and navigation control, could create a much closer connection between subject and abstraction.

Further developments on the setup

- The navigation should be change so the subjects have access to a much larger degree of freedom
- The current control devices should be replaced with one other device, e.g. a track-ball mouse
- The audience behaviour should interact with the subjects
- Developing further on the audio design to create coherence with the visualizations
- Interactions could be added the setup by tracking the objects or the subject in order to enhance the subject's connection to the virtual world, making the environment a more flexible dimension.
- It could be interesting to add the real-time depth cue testing with stereo glasses
- Continuing work with animated virtual environments

Example of interaction possibilities

- Tracking the subject's hands. If the arms are raised, above a certain threshold, the audience would start a wave by the audience on a stadium. Lowering the arms makes the wave stop gradually
- Tracking collision between a physical object, e.g. a ball, and create audio feedback with the appearance of being in a large room.
- Placing the subject on a virtual camera. Extracting the subject by using a green screen and background subtraction, record background image of the virtual background to the virtual subject position and then assemble virtual background with the isolated image of the subject and send it to the virtual camera to be updated real-time.
- The audience move according to subject position

10 Bibliography

1 Wang, Y.; Otitoju, K.; Liu, T.; Kim, S.; Bowman, D. A. (2006). *Human factors I: Evaluating the effects of real world distraction on user performance in virtual environments*. Proceedings of the ACM symposium on Virtual reality software and technology VRST '06, ACM Press.

2 Brogni, A.; Vinayagamoorthy, V.; Steed, A.; Slater, M. (2006). *Human factors II: Variations in physiological responses of participants during different stages of an immersive virtual environment experiment*. Proceedings of the ACM symposium on Virtual reality software and technology VRST '06, ACM Press.

3 Mastoropoulou, G.; Debattista, K.; Chalmers, A.; Troscianko, T. (2005). *Papers: animation: The influence of sound effects on the perceived smoothness of rendered animations*. Proceedings of the 2nd symposium on Applied perception in graphics and visualization APGV '05
Publisher: ACM Press

4 Sanchez-Vives, M. V.; Slater, M. (2005). From presence to consciousness through virtual reality. *Nature Neuroscience*, 6(4):8-16.

5 Nunez, D. (2004). *NPR environments: How is presence in non-immersive, non-realistic virtual environments possible?* Proceedings of the 3rd international conference on Computer graphics, virtual reality, visualisation and interaction in Africa AFRIGRAPH '04, ACM Press.

6 Slater, M.; Brogni, A.; & Steed, A. (2003). *Physiological Responses to Breaks in Presence: A Pilot Study*. In Proceedings of the 6th International Workshop on Presence. Aalborg, Denmark, 6-8 October 2003.

7 Slater, M (2003). A Note on Presence Terminology. *Presence-Connect*, 3 (3).

8 Naef, M.; Staadt, O.; Gross M. (2002). *Applications: Spatialized audio rendering for immersive virtual environments*. Proceedings of the ACM symposium on Virtual reality software and technology VRST '02, ACM Press .

9 Meehan, M.; Insko, B.; Whitton, M.; Brooks, F. P. (2002). *Physiological measures of presence in stressful virtual environments*. ACM Transactions on Graphics (TOG) , Proceedings of the 29th annual conference on Computer graphics and interactive techniques SIGGRAPH '02, Volume 21 Issue 3
Publisher: ACM Press.

10 Storms, R. L.; Zyda, M. J. (2000). Interactions in Perceived Quality of Auditory-Visual Displays. *Presence*, Vol. 9, No. 6, pp.557-580.

11 Pulkki, V. (2000). *Generic panning tools for MAX/MSP*. Proceedings of International Computer Music Conference 2000. pp. 304-307.

12 Usoh, M.; Arthur, K.; Whitton, M. C.; Bastos, R.; Steed, A.; Slater, M.; Brooks, F. P. (1999). *Walking > walking-in-place > flying, in virtual environments*. Proceedings of the 26th annual conference on Computer graphics and interactive techniques SIGGRAPH '99, ACM Press/Addison-Wesley Publishing Co.

13 Slater, M. (1999). Measuring Presence: A Response to the Witmer and Singer Presence Questionnaire. *Presence: Teleoperators and Virtual Environments*, 8(5): 560-565.

14 Witmer, B. G.; Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, 7(3):225-240.

15 Matlin, M. W.; Foley, H. J. (1997). *Sensation and Perception*. Massachusetts: Allyn and Bacon

16 Slater, M.; Usoh, M.; Steed, A. (1995). *Taking steps: the influence of a walking technique on presence in virtual reality*. ACM Transactions on Computer-Human Interaction (TOCHI), Volume 2 Issue 3, ACM Press.

17 Barfield, W., T. Sheridan, D. Zeltzer and M. Slater (1995). Presence and performance within virtual environments. In Barfield, W.; Furness, T. (ed.), *Virtual environments and advanced interface design*. London: Oxford University Press.

18 Barfield, W.; Furness, T. (1995). *Virtual environments and advanced interface design*. London: Oxford University Press.

19 Heeter, C (1992). Being There: The Subjective Experience of Presence. *Presence: Teleoperators and Virtual Environments*.

20 Virtools client building block accessed on May 20th, 2007. Url: http://www.theswapmeet-forum.com/

21 Max/MSP OSC objects accessed on May 20th, 2007. Url: http://recherche.ircam.fr

22 Max/MSP RVBAP objects accessed on May 20th, 2007. Url: http://www.akustische-kunst.org/maxmsp/

23 Descriptions of expressions http://en.wikipedia.org

24 R-project software accessed on May 20th, 2007. Url.: http://www.r-project.org/

11 Disclosures

11.1 CD-ROM

Folder “Audio design”:

- Folder “MaxMSP externals”
  - monoverb~1.0.zip
  - OSC-package-1.5.1-winXP.zip
  - rvbap.zip
- Folder ”MaxMSP patch and audio clips”
  - active4.wav
  - active5.wav
  - Audio_Design.pat
  - passive1.wav

Folder “Questionnaire”:

- Questionnaire.doc

Folder “Report”:

- A_CROSS-MODAL_ENHANCED_MULTI-DIMENSIONAL_VISUALIZATION.doc
- A_CROSS-MODAL_ENHANCED_MULTI-DIMENSIONAL_VISUALIZATION.pdf

Folder “Test documentation”:

- Test.avi
- Test_0001.jpg – Test_0009.jpg

Folder “Visualization”:

- Folder “Maya files”
  - Arena.mb
  - CharA1.mb / CharA2.mb / CharA3.mb
  - CharB1.mb / CharB2.mb / CharB3.mb
  - CharC1.mb / CharC2.mb / CharC3.mb
  - CharD1.mb / CharD2.mb / CharD3.mb
- Folder ”Maya textures””
  - Court.jpg
  - CourtFloor.jpg
  - GoalFrame.jpg

- Folder “Virtools extra objects”
  - OSC-GPL.zip
- Folder “Virtools files”
  - A_CROSS-MODAL_ENHANCED_MULTI-DIMENSIONAL_VISUALIZATION.cmo

Appendices

Appendix A: Questionnaire

Date _____

Questionnaire: Personal data

Test group: _____

Test subject no.: _____

Male ☐ **Female** ☐

Age _____

Occupation _____

If student, what is your education _____

Do you accept video recording of you during the test **YES** **NO**

Do you accept photography of you during the test **YES** **NO**

Questionnaire: Test data

Choose an answer from 1 to 5 **1 = very little 5 = very much**

1) How natural did your interactions with the environment seem?
1 2 3 4 5

2) How completely were all of your senses engaged?
1 2 3 4 5

3) How much did the visual aspects of the environment involve you?
1 2 3 4 5

4) How much did the auditory aspects of the environment involve you?
1 2 3 4 5

5) How natural was the mechanism which controlled movement through the environment?
1 2 3 4 5

6) How aware were you of events occurring in the real world around you?
1 2 3 4 5

7) How aware were you of your display and control devices?
1 2 3 4 5

8) How inconsistent or disconnected was the information coming from your various senses?
1 2 3 4 5

9) How much did your experiences in the virtual environment seem consistent with your real-world experiences?
1 2 3 4 5

10) How completely were you able to actively survey or search the environment using vision?
1 2 3 4 5

11) How well could you identify sounds?
1 2 3 4 5

12) How well could you localize sounds?
1 2 3 4 5

13) How compelling was your sense of moving around inside the virtual environment?
1 2 3 4 5

14) How involved were you in the virtual environment experience?
1 2 3 4 5

15) How distracting was the control mechanism?
1 2 3 4 5

16) How much delay did you experience between your actions and expected outcomes?
1 2 3 4 5

17) How quickly did you adjust to the virtual environment experience?
1 2 3 4 5

18) How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?
1 2 3 4 5

19) How much did the visual display quality interfere or distract you from performing assigned tasks?
1 2 3 4 5

20) How much did the control devices interfere with the performance of assigned tasks?
1 2 3 4 5

21) How well could you concentrate on the assigned tasks rather than on the mechanisms used to perform those tasks?
1 2 3 4 5

22How much time do you think the test lasted?
1-4 min 4-8 min. 8-12 min. 12-16 min. 16-20 min.

Comments?

_____

_____

_____

_____

_____

Thank you for your time!

Appendix B: Test results

Test setup number	**1**				**2**				**3**			
Test subject number	**2**	**6**	**11**	**12**	**3**	**4**	**8**	**10**	**1**	**5**	**7**	**9**
Question no. 1	2	2	1	2	5	3	2	2	3	4	3	3
Question no. 2	2	2	2	2	5	4	2	5	4	4	3	4
Question no. 3	4	5	2	3	5	4	2	4	5	5	3	4
Question no. 4	0	0	0	0	5	3	4	1	5	4	3	1
Question no. 5	3	1	3	1	3	2	1	1	2	3	1	2
Question no. 6	2	4	2	2	4	1	3	1	1	1	2	3
Question no. 7	5	4	2	3	5	4	5	5	3	4	4	4
Question no. 8	3	3	1	2	5	4	3	4	1	2	3	2
Question no. 9	3	1	2	3	4	1	2	3	3	4	3	3
Question no. 10	4	4	3	4	4	2	3	5	3	5	3	4
Question no. 11	0	0	0	0	5	3	4	1	5	5	5	5
Question no. 12	0	0	0	0	4	1	5	2	3	4	4	2
Question no. 13	2	4	2	3	5	2	3	4	3	5	3	3
Question no. 14	3	2	2	3	4	4	3	4	4	5	2	3
Question no. 15	1	4	3	4	3	4	5	3	4	3	3	3
Question no. 16	3	4	1	1	5	2	5	2	3	2	2	3
Question no. 17	4	4	4	4	4	2	4	4	3	5	5	5
Question no. 18	5	5	4	5	5	3	4	3	5	5	3	3
Question no. 19	2	2	1	1	3	3	5	1	1	1	2	2
Question no. 20	3	2	4	5	1	5	5	4	2	3	2	1
Question no. 21	2	4	5	5	5	2	2	5	5	4	3	5
Question no. 22	2	2	2	2	2	2	2	2	2	3	2	2
Actual time interval	3	2	1	1	2	2	2	1	3	3	1	1
Precise used time/minutes	9	6	4	4	5	5	5	4	12	10	3	3

Appendix C: Test subject comments

Test subject 1
The movements with the keyboard were a bit jerky and too slow.
It would be more fun if one could move and rotate faster and smoother.
I liked the virtual environment very much.
It was fun to navigate inside the virtual arena.
The people inside the arena made me feel a bit angry when they were cheering even if I was not finding the objects.
The visual effect while going down from the staircase was cool.

Test subject 2
You need to get used to the interaction modality (arrows and movement associated) at the first sound.
Then it is very easy to navigate and predict system reaction to your own movements.

Test subject 3
BLANK

Test subject 4
The person is running and turning too slow

Test subject 5
Spændende oplevelse.
God sammenhæng mellem lyd og bevægelse.
Det ville være en god ide at kunne prøve det 2 gange.

Test subject 6
BLANK

Test subject 7
BLANK

Test subject 8
No head movements – it's like a lost child is looking for his mom.
Sound quite OK.
The graphics unfortunately puts clearly "the artificial border" between the reality and virtual reality.

Test subject 9
BLANK

Test subject 10
Turning slow.

Test subject 11
Really missed the option to look up and down
Really missed the option to be able to walk sideways

Test subject 12
The world seemed quite realistic because of (what I think) was random, but expected behaviour of the crowd, i.e. the waving of the arms from some of them. It seemed like a game was going on.

Appendix D: Equipment specifications for the setup

Personal computer 1 (visualization):

- Intel Pentium D
- CPU 3.00 GHz
- 2.00 GB RAM
- Graphic card (projector) NVIDIA Quadro FX 1400
- Card memory size 128 MB
- Screen refresh rate 100 Hz
- Microsoft XP Professional Version 2002

Personal computer 2 (audio):

- Intel Xeon
- CPU 3.00 GHz
- 1.00 GB RAM
- Microsoft XP Professional Version 2002

Audio interface:

- RME Fireface 800

Speakers:

- M-Audio
- Model : Studiophile BX8
- Input IMP : 20K OHM Bal./10K OHM Unbal.
- Input sensitivity : 85 mV / 9, dB / 1M
- LF Amp. Power : 65 W / HF Amp. Power: 65 W
- Frequency response : 37 Hz – 20 KHz