

The Virtual Wine Bar Experiment

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The Virtual Wine Bar and Underground Train Experiment was a joint project by Laura K James and Chien-Yu Lin. The design and execution of the experiment was a joint task. The initial writing of the programs was pursued jointly, additional writing of the programs was done separately as detailed in section 1.3 of this report.

The research of background literature and previous experimentation; the analysis of the experiment's results; and the presentation in the form of a thesis – the essay that follows – were carried out individually and without consultation as to the other's opinion in any matter.

This report is submitted as part requirement for the MSc Degree in Vision, Imaging and Virtual Environments at University College London. It is substantially the result of my own work except where explicitly indicated in the text. The report may be freely copied and distributed provided the source is explicitly acknowledged.

Abstract

Can virtual reality be used to treat those suffering from social phobia? In order to answer this a further question is posed. Do people interact with and react to virtual humans as they would with real people? The purpose of this project was to find out the answer to the latter question. An experiment was devised whereby subjects were placed in a virtual wine bar and an underground train populated by avatars (virtual humans). Half of the subjects went into the wine bar first and then the train and the other half vice versa.

The subjects were asked to make conversation with the avatars in the wine bar, a task that someone who suffered from social phobia would find extremely uncomfortable if not impossible. The avatars were designed to be impolite and disinterested in the subjects. The train scenario was designed to be a neutral environment with lesser degree of interaction on the part of the subject (they were not expressly told to speak to the avatars).

Questionnaires were used to determine the subject's level of social phobia prior to the experiments and their level of discomfort during and after the experiment.

It was found that the level of discomfort rose after the experiments in the majority of cases, especially in the wine bar scenario. Also, the subjects were found to act and react to the avatars, as they would real people.

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1 Introduction

1.1 Project Aims

Social Phobia is a condition where the sufferer exhibits extreme anxiety in social situations such as giving a presentation or introducing themselves at a party. The condition can be generalised i.e. the patient shows symptoms in the majority of social situations, or it can be restricted to a particular type of situation (“discrete” social phobia).

According to the European Description [1], The following all need to be true in order for a person to be classified as socially phobic:

“(a) The psychological, behavioural, or autonomic symptoms must be primarily manifestations of anxiety and not secondary to other symptoms such as delusions or obsessional thoughts; (b) the anxiety must be restricted to or predominate in particular social situations; and (c) avoidance of the phobic situations must be a prominent feature.”

This project is designed to establish whether or not people act the same way in a virtual environment, reacting and interacting with avatars (virtual humans) as they would in the real world. If it is found that people *do* act the same in virtual environments with avatars as they would in the “real” world with people then virtual reality could be used to treat people suffering from social phobia. This would have tremendous positive implications for the social phobia sufferers as they could then approach social situations with renewed confidence.

1.2 Scope

The environment that is to be created, along with the avatars, is not going to be photo-realistic. The reasons for this being that the creation of a real-time photo-realistic virtual environment would not only be incredibly time-consuming to create but it would also take a long time to render thus making the frame rate unacceptably low. However, the mannerisms of the avatars are designed to be realistic for the environment that they are to be in. The environment for this experiment is to be a wine bar scenario therefore the avatars are to act as people would in such a place.

The emphasis will be on the subject talking to the avatars and not the other way round. This means that the avatars will only have a small finite set of phrases to “speak”. The reasons being:

- (1) The more that the avatars speak the more they will be expected to speak and therefore either a very restricted or very large vocabulary is required. A large vocabulary would be large to store and complex to remember how to trigger each voice clip.
- (2) The purpose of the experiment is to find out how the subject reacts and interacts with the avatars. It is proposed that limiting the vocabulary of the avatars will mean that if the subject is socially phobic they will show anxiety, thinking that the avatars are not interested in them. However, if the subject is confident and not socially phobic then they will be more likely to speak to the avatars in an attempt to elicit information from them.

1.3 Contributions

The basis of the program is the VR Juggler Cubes sample program.

The following classes were written by the author, Chien-Yu Lin and Samuel Pang as part of a group project for MSc VIVE Virtual Environments module: Vertex, Triangle, Color also the read_file class method from which the read_joint and read_segment methods were adapted.

The author and Chien-Yu Lin wrote the Avatar class and the following Avatar class methods: read_joint, read_segment, create, hexdec.

The author and Chien-Yu Lin wrote the first implementation (see §4.1.2) of the following classes and methods: Segment, Joint and the new code in myDraw. The final implementation (again see §4.1.2, also Appendix J) was written by the author.

The author wrote all of the new code in preFrame, init and the following avatar class methods: actions, shrug, walk, talk, nod, shakeHand, vacant, rotateHead, drink and checkhex.

Mel Slater constructed the information sheet, consent form and the pre- and post-experiment questionnaires used in assessment of the subjects (Appendices A-D).

1.4 Report Structure

The following sections will be covered in this report:

Chapter 2: Background to the project, introduction to the subject of social phobia and how virtual reality has been used in psychotherapy

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- Chapter 3: Description of the skills that were learned for the project
- Chapter 4: How the project was designed and the skills that were implemented to write the project
- Chapter 5: Purposes of the experiment, a high level design of the experiment, description of how subjects were recruited, details of the questionnaires used, the data being collected and hypotheses made
- Chapter 6: The experiment
- Chapter 7: Results, qualitative and quantitative findings of the experiment
- Chapter 8: Conclusions
- Chapter 9: Bibliographic listing of books, papers and websites
- Chapter 10: References

2 Background

2.1 Description of Social Phobia

Many people when having to go into any social situation such as giving a presentation will feel a certain level of anxiety or ‘butterflies’. They will think of all the things that could go wrong and imagine that those around them will regard them in a negative manner. Usually, once in the given situation the person will be able to perform the task and their feelings of anxiety will disappear. This is a normal situation for the majority of people. However, for a small minority of people this fear becomes excessive and reaches extensively into the social situation making the person display signs of extreme anxiety such as sweaty palms, stammering, blushing and nausea. In such situations they are in extreme fear of embarrassing or humiliating themselves. This condition is known as social phobia and it usually means that they try to avoid such social encounters at all costs.

Generalised social phobia means that the person displays fear in the majority of social situations. However, certain people are socially phobic of particular social situations such as giving presentations or eating in front of others. The extent of the fear is often such that it prevents the sufferer from leading a normal life, as they may sometimes feel unable to go outside or go to work. This condition is known as discrete social phobia.

Most socially phobic people realise that their fears are unfounded and that people are not really judging them all of the time. However, despite knowing this, they still feel the same when placed in the social situation and also react to people with the same degree of nervousness and embarrassment. These reactions are like habits in that they happen without premeditation. Therapy aims to help the sufferer “unlearn” these automatic responses; the various methods of therapy/treatment are detailed in the following section.

2.2 Methods of Treatment

According to The Social Anxiety Institute [2] *“It is estimated that 7-8% of the population suffers from some form of social anxiety at the present time”* and that social anxiety affects men and women equally. It is also the third most common psychiatric disorder after depression and alcoholism. However it is treatable through a number of methods:

- (1) Self-help: by going to self-help groups, support groups or to confidence building classes
- (2) Drug Treatment: Beta Blockers, anti-depressants, tranquillisers
- (3) Psychological Treatment: Exposure therapy/ Cognitive-Behavioural Therapy.

2.2.1 Self-Help

People with social phobia often end up feeling lonely as a result of their condition because they avoid social situations due to the anxiety that is elicited. Through self-help groups, sufferers can help to break the feeling of isolation. The Social Anxiety Support Group in the West of England is one of these groups. People who have suffered with or are still suffering from social phobia/anxiety lead the group. Within the group, information on social phobia and treatments for it, such as Cognitive Behavioural therapy (see §2.2.4), are discussed.

2.2.2 Drug Treatment

Drug treatments such as Beta-Blockers (given in small doses) can help alleviate the symptoms of social phobia such as sweating. This can be useful for a sufferer if they need to go to an interview, for example. However, they are not a cure for the psychological part of the disorder.

2.2.3 Exposure Therapy

Exposure therapy is the means by which a person with a phobia, such as fear of spiders (arachnophobia), is helped to relax when in the presence of the cause of the phobia. The sufferer is gradually exposed to the source of the fear so they remain calm thus building up their tolerance to the stimulus. Their fear will probably never completely leave them; however, it will generally be reduced to a level that means they will not panic when they come across their fear stimulus.

2.2.4 Cognitive Behavioural Therapy

Cognitive therapy is where the sufferer is taught to re-learn the way they think about themselves and how they react in the situation that causes them distress. For example, if they think that when they walk into a bar everyone is looking at them and judging them, cognitive therapy helps them to realise that most people are not even looking in their direction. Even if they are being watched they learn that it is not necessarily for a negative reason. The patient generally feels that “negative” reactions from those around them are their own fault. However, in therapy they are taught that, for example the pause in the conversation could just be because the other person is tongue-tied and not because they are bored with what they are saying.

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The method of Cognitive Therapy along with *in vivo* (in life) exposure therapy is known as Cognitive-Behavioural Therapy. In this, patients are taught to think differently about the cause of their phobia and during treatment are taught to unlearn their automatic response to the stimulus through exposure therapy. It is this method of treatment that has been found to work the best.

Pavlov [3] noted the learning of conditioned responses when he rang a bell when giving his dog food. After a time whenever Pavlov rang a bell the dog would salivate at the thought of food whether or not food was present. The dog had been conditioned to associate the ringing of the bell with food. Conditioned responses are therefore learned. However, it has been found that conditioned responses can be unlearned [4]. Therefore, if the bell was rang a number of times without food being presented over time the dog would cease to salivate at the sound of the bell, indicating that the conditioned response had been unlearned.

Phobias are responses that have been 'learned' by the sufferer over time. As they are learned responses it is thought that, like Pavlov's dog, the conditioned responses can be unlearned. Cognitive-Behavioural Therapy has been found to be a very effective method of treatment for a range of anxiety disorders (with a few exceptions) and has been found to be the most successful method of treatment for those suffering from social phobias.

2.3 Virtual Reality in Psychotherapy

People suffering from a phobia generally realise that the situation or object is harmless. For example they "know", if they are socially phobic, that people are not staring at them all of the time and they "know", if they suffer from arachnophobia, that a house spider is completely harmless. However, this does not tend to stop them feeling anxious at the source of their fear. Virtual reality has been used fairly extensively to help treat people who have a fear of heights, flying etc through exposure therapy. Exposure to the cause of the phobia is increased gradually in the virtual environment in controlled steps. This leads to an acceptance of the anxiety stimulus and the person becomes able to accept the situation with a less extreme anxiety reaction. This can continue until the person's tolerance is built up and they feel at ease with the situation to a degree with which they are content.

Why use virtual reality for exposure therapy instead of in vivo exposure, i.e. exposure to the phobia in the real world? Primarily, depending on the phobia, it can be very difficult to keep recreating the same scenario with which to expose the person. Additionally the costs are high for in vivo exposure. To take an extreme example, the use of exposure therapy for someone with a fear of flying (aviophobia) would be incredibly costly because many flights would have to be taken in order to treat the phobia using in vivo techniques. However, to treat the same phobia using virtual reality (after the initial outlay of the virtual reality equipment) is very low cost and the stages of exposure can be incrementally built up to gradually reduce anxiety.

Another reason for using virtual reality is the complete control that the therapist can have on the situation as they can stop the simulation at any time and go to any part of the simulation that is required. Potential physical harm to the person is also reduced to that of the equipment; any harm from use of the virtual reality equipment such as neck or eyestrain can be virtually eliminated by keeping exposure times constrained.

2.4 Research into using Virtual Reality for Psychotherapy

2.4.1 Arachnophobia: Fear of Spiders

The research into helping sufferers of arachnophobia through virtual reality was instigated by a sufferer of the phobia for twenty years; a “Miss Muffet” [3]. She had seen a program on helping to cure fear of heights through virtual reality and came to the conclusion that the arachnophobia from which she suffered might also be treatable using virtual reality. Her symptoms of the phobia had become so acute that she sealed her windows with duct tape at night, wrapped her clothes in plastic bags after washing them to make sure no spiders got in, and became hesitant to leave her house.

Research was pursued at Washington University using virtual reality to help cure sufferers of arachnophobia. Initially the patient was placed at the opposite end of the virtual environment to the spider. The patient gradually went closer to the cause of their fear, in this case the spider, in the virtual environment. To begin with their anxiety was markedly increased. However, after persistence (typically, less than twelve hours) their anxiety decreased with exposure to the virtual spider such that they could pick it up (figure 1).

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Figure 1: View of subject's virtual hand grabbing the virtual spider

There were a number of spiders in the environment that were programmed to move in different ways: one fell down from the ceiling and one climbed. The spiders could also be made to jump at unexpected moments by the therapist. The signs of fear such as increased heart rate, sweating diminished through exposure. The subject also had some facts explained to them about spiders. In this way the subject's conditioned response to spiders was gradually broken down.

Miss Muffet had about twelve one hour therapy sessions planned (one a week for three months). After about nine of these she seemed to be in control of her anxiety. Therefore, to try and provoke anxiety the researchers installed a furry toy spider into the world so that when Miss Muffet touched a virtual spider she felt the toy one. Previously, she had no sense of touch, as there was no haptic¹ feedback built into the virtual environment. This did provoke anxiety at first, as had been expected. However, she did get used to the 'new' spider. This mixing of stimuli from both the real and virtual world is known as *augmented reality*; in the "Miss Muffet" treatment it increased the number of senses that were being employed in the experience from two (sight and sound) to three (with the addition of touch).

Following this therapy Miss Muffet was able to approach real house spiders without anxiety and was cured to the extent that she could lead a normal life again without having to take all the anti-spider precautions (such as sealing the windows) that she had done previously. Miss Muffet was the first to use virtual reality *in vivo* exposure therapy to treat arachnophobia. Since then the same team has treated twenty phobics with approximately 85% success.

¹ Haptics: the study of sensing and manipulation through touch (definition from MIT Touch Lab: <http://touchlab.mit.edu/>)

In vivo exposure therapy for patients with specific phobias such as vertigo or agoraphobia has been found to have an extremely high success rate generally taking twelve hours or less [3].

2.4.2 Acrophobia: Fear of Heights

“Acrophobia is defined by three elements: fear of heights, avoidance of heights, and difficulty functioning in everyday life due to height anxiety” [5]. People with acrophobia will go to great lengths to avoid being off the ground such as continuous circling of multi-storey car parks until a space on the ground floor becomes vacant. One such sufferer, Christopher Klock, is now cured thanks to eight weekly treatment sessions at Emory-Georgia Tech using Virtual Reality.

Treatment of acrophobia, as with most phobias, has traditionally been approached using exposure therapy. The patient will be taken to a first floor window, say, then gradually be exposed to higher heights such as bridges and skyscrapers. However, this can be costly and take up a lot of time. Virtual Reality on the other hand, as mentioned, has the benefits of being low-cost (once the system is up and running) and the environment is controllable by the therapist.

For the study at Emory-Georgia Tech, twenty people were selected with eight being control subjects (i.e. having no treatment) and the remaining twelve participating in virtual reality exposure therapy. The virtual environments that the subjects were placed in were a mountain gorge spanned by bridges, balconies on a tall building and a glass elevator.

After exposure to these virtual environments the anxiety of the patients who took part was decreased significantly from the anxiety they experienced before exposure. There was no difference in the anxiety levels of the control subjects.

It was found that the subjects were more willing to place themselves in situations that would normally cause them distress because they knew they were not really real. However, during therapy the subjects still experienced prominent signs of anxiety and distress such as sweaty palms, increased heart rate and dizziness, though to a lesser extent than if they had been in the real situation. In-between treatment sessions, ten of the twelve subjects actually took themselves to height situations such as a glass elevator even though they had not been asked to do this; they found that they could cope with the situation which previously would have been avoided at all costs.

2.4.3 Aviophobia: Fear of Flying

Research into using virtual reality for treatment of people who suffer from a fear of flying has been done at the Centre for Advanced Multimedia Psychotherapy at the California School of Professional Psychology (CSPP). Those who have aviophobia approach the cause of their anxiety in one of two ways: they either do not fly or they have to take sedatives and/or alcohol to calm down sufficiently to cope.

The Centre treats patients by getting them to wear a head-mounted display through which they see themselves in the passenger cabin of a commercial aeroplane. During the eight training sessions the patient experienced the following scenarios: sitting on the aircraft with the engines off, sitting on the aircraft with engines on, taxiing on a runway, taking off, flying in good weather, flying in a storm and landing. In this way the patient was gradually de-sensitised to flying. The therapist was in complete control of the environment and could stop the simulation at any time if necessary. The environment and environment variables could also be changed as appropriate.

2.4.4 Post-Traumatic Stress Disorder

Virtual reality has also been used *in vivo* psychotherapy for the treatment of Vietnam War veterans suffering from post-traumatic stress disorder (PTSD) at Emory University, the Georgia Institute of Technology and the Department of Veterans Affairs Medical Center (Atlanta). For many of the veterans, just the sound of a helicopter can trigger flashbacks causing considerable distress. virtual reality was employed to try to help the veterans using exposure therapy. The virtual reality environments included a helicopter flight over terrain that would be found in Vietnam (such as rice paddy fields) and a walk through a jungle. Relevant sounds would be played such as gunfire, screaming and jungle noises. Virtual Reality was employed to alleviate post traumatic stress syndrome due to actual exposure therapy being impractical (taking the veterans back to Vietnam or to a war would clearly not be a realistic possibility).

The results found so far in treating post-traumatic stress disorder have been promising “*patients who completed the treatment have shown as much as one-third reduction in severity of symptoms and significantly fewer nightmares, flashbacks, intrusive thoughts, depression and anxiety. ‘We don’t expect to cure, but we have found reductions in symptoms and behaviour in most patients,’ he [Dr Ready] related.*” [6]

2.5 Research into Using Virtual Reality to Treat Social Phobia

As has been seen, a lot of research has been undertaken in using virtual reality to help treat people with various phobias such as arachnophobia, etc. However, research into helping treat people with social phobia is only just beginning.

Exploratory research into using virtual reality in the treatment of social phobia has been undertaken at University College London by Pertaub, Slater and Barker [7]. The social situation that they researched was public speaking and the purpose was to try and establish if the anxiety of the subject could depend on the reactions and actions of the avatars. Negative, positive and static audiences were designed to measure the extent, or otherwise, of the subjects' reactions to the different types of audiences.

A virtual environment was created of a seminar room with a table surrounded by eight male avatars seated on chairs (figure 2). The subjects then had to give at least two talks to the group of avatars. Each subject was randomly assigned one of three groups determining what response category the avatars would fit into for the first experiment:

1. Static (no response from the avatars)
2. Positive (the avatars smiled and made eye contact)
3. Negative (the avatars looked disinterested).



Figure 2: Male avatar

The experiment was a success as it was found that the subjects interacted with and reacted to the avatars as they would if giving a presentation to real people. The subjects felt less nervous with the group of avatars that responded positively than the group that responded negatively where they experienced discomfort.

Additional findings were that a feeling of presence in the virtual environment was likely to be maintained as long as the timing of the responses made by the avatars was realistic.

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As has been seen, a large amount of research has been carried out into the use of Virtual Reality *in vivo* exposure therapy for people with a number of different phobias and for those with post-traumatic stress disorder with very good results. These findings provide a platform for the supposition that virtual reality could also be used in treating people with social phobia. However, very little research has been performed into using virtual reality as treatment for social phobia; indeed, before it can be used there must be evidence that people react to virtual humans (avatars) as they would to real people.

Initial studies at University College London (as detailed above) indicate that people do respond in the same way to avatars as they would to real people. However, more experiments need to be conducted before this can be taken as definite and research into using virtual reality in treating those with social phobia can be commenced.

Thus this project has been undertaken in order to gather more results and to advance knowledge in the field. It was accomplished by creating a virtual environment populated with avatars with which the subject would have to interact. It was considered that an appropriate environment would be a wine bar because many people are familiar with such an environment. The avatars were designed to reflect the appearances and behaviour of a student clientele as it was likely to be from the student population that the subjects would be taken. The details of the project and the results obtained are to be found in the following chapters.

3 Technical Background

The program for this project was written in C++ with OpenGL for the graphics and VR Juggler to interface with the CAVE, the chosen method of implementation. The code was run on Silicon Graphics machines. However, much of the code had been written in Visual C++ under Windows on the author's PC then altered, where required, to run on the SGIs.

There were a number of skills that had to be learned and improved upon in order to complete this project. These skills included learning programming languages, 3D modelling and avatar animation.

3.1 Languages: C++, OpenGL, VR Juggler

Prior to the project, the only knowledge of C++, OpenGL and VR Juggler that the author had was basic and gained when writing coursework for the MSc VIVE degree.

3.1.1 C++

C++ is a high-level object oriented programming language, which is extensively used by programmers.

Having had little knowledge of C++ prior to this project, during this project the author came to understand the purpose of classes and inheritance to a much greater extent as well as the thorny problems of pointers, referencing and de-referencing.

3.1.2 OpenGL

On an undergraduate computer science course the principles of 2D graphics programming are likely to be taught: how to “draw” a dot (or colour a pixel) on the screen. From this algorithms for drawing lines are taught, progressing onto drawing boxes and circles then flood-filling them. Then how to crop a picture to the window it is to be drawn in.

In an advanced course the principles of “3D” graphics programming are likely to be taught where, although the data structure may hold data for a 3D object, the output is still to a 2D device but has the added property of perspective to make it *appear* to be 3D. Concepts such as data structures for storing 3D object information (vertices, edges, polygons), shading models, computing parallel and perspective projection of a scene and rear-face culling are usually taught.

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This is all very useful but once the basics of graphics programming have been mastered it would be very tedious to have to re-write all of the line drawing and projection algorithms when wanting to create, “Toy Story”, for example. This is where OpenGL comes in.

OpenGL is an API¹ (Application Programming Interface) for 3D computer graphics with a large modelling library that is fast and portable across platforms. So what does this really mean? It means that instead of coding all of the algorithms as mentioned above, a single call to an inbuilt OpenGL function can be made to draw a line or polygon. Additionally all of the projection matrices and lighting computations are calculated automatically with a few simple commands. OpenGL is not a programming language in its own right it, it is more like pre-written code that can be embedded in a C++ (or other suitable language) program to save the programmer from writing their own graphics methods.

Prior to the MSc VIVE course the author had no knowledge of OpenGL. Through writing two pieces of coursework some basic knowledge of the API was learned. It was only through the writing of this project that more comprehensive knowledge was gained.

3.1.3 VR Juggler

VR Juggler is an API that is used to simplify the interfacing elements required in virtual reality programs such as stereo graphics, tracking and rendering. VR Juggler is platform, VR system and device independent making it highly portable. This added flexibility to the writing of this project as it could be written both at home on a PC and at University College London both on the Silicon Graphics workstations displaying on a CRT and in the Cave (Cave Automatic Virtual Environment, see §3.2).

In order to be able to trigger animations and sounds from keyboard presses an input window needed to be active. When running in simulator mode a window appeared on the screen which, when active, meant that keyboard input could be understood. However, when running the program in the Cave this window was not present. Through talking with the VR Juggler help group it was discovered the window that had been appearing was actually there to simulate the head tracker, hence why it did not appear when running the program in the Cave as the actual head tracker was present.

¹ API (Application Programming Interface): A set of functions that are created to be used by programs in order for the operating system to do the hard work by sending a single instruction.

To solve this problem, an additional configuration file needed to be written to create a window, which would appear both when running the simulator on an SGI or PC and in the Cave. The new configuration file `lauraConfig` (Appendix K) was based on the `sim.wand.mixin.config` file.

3.2 Equipment: CAVE

The CAVE is the ‘device’ on which this project scenario was displayed. The CAVE is comprised of four screens- three walls and a floor on which are projected stereo pairs of images. The user inside the CAVE wears special glasses that are designed so that one side suppresses one of the images in the stereo pair and lets through the other; the other side will let through the image that was suppressed by the first side.

A head tracker is worn to keep track of where the user is inside the CAVE to keep the projected images in synchrony with their position. Additionally a hand tracker or “wand” can be held to give additional information on the location of the subject. The wand also incorporates a joystick for “flying” through the environment, so that the user can use it to “move” large distances in the environment, and some buttons that can be programmed for various uses such as object selection.

The CAVE was used instead of a head-mounted display (HMD) as it has better resolution and a greater field of view. Additionally, the CAVE is preferable from a health and safety issue as the glasses and head tracker are much lighter than a HMD and are therefore less likely to cause neck strain. Also, when wearing a HMD the user has to focus on something that is very close which can cause eyestrain. In the CAVE the distance from the user’s eyes to the picture is much greater, the same as if the person was in a real environment.

3.3 Modelling: AC3D

Previously AC3D had been used by the author to model basic animals using the sphere, cylinder and box primitives. However, to create an avatar of more realistic proportions more complex modelling skills had to be learned such as deforming the basic primitives, using meshes, extrusions, deleting non-visible portions of meshes to reduce polygon count without reducing the detail.

3.4 Sound

The sound (voice clips) for the project was recorded using Microsoft sound recorder and a microphone on the author's PC and saved in waveform (.wav) format. The female voice in the program is that of the author and the male voice is that of James Stringer.

The experiments and interviews that the subjects allowed to be recorded were audio-recorded using minidisk players supplied by the author's colleague Chien-Yu Lin.

4 Program Design & Implementation

There were three main parts involved in creating the project:

1. Design and implementation of the avatar hierarchy
2. Designing/modelling the environment and avatars
3. Animating the avatars

Each of these is discussed in more depth in the following sections.

4.1 Avatar Hierarchy

4.1.1 Design of Avatar Hierarchy

To make the avatars move in a realistic manner, a joint hierarchy was used similar to that of the human skeleton. For example, the elbow joint is a child of the shoulder joint and therefore inherits characteristics of the shoulder joint. This means that movement of the shoulder impacts on the position and orientation of the elbow.

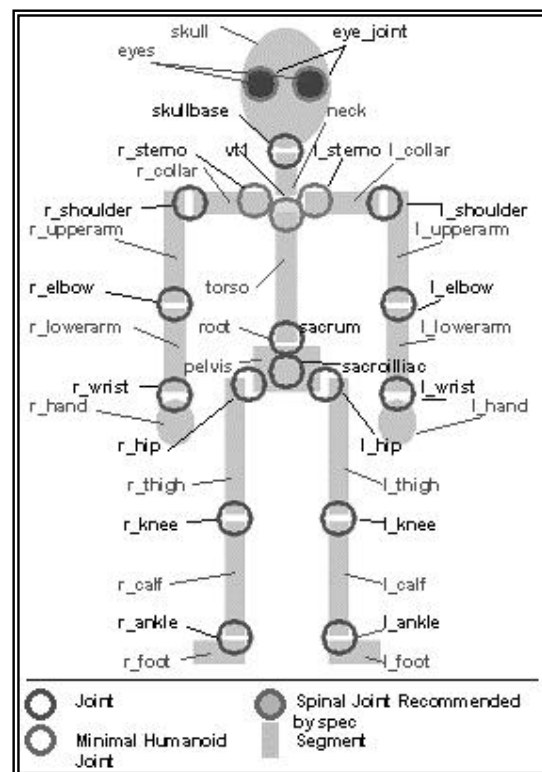


Figure 3: Avatar Joints and Segments

The H-Anim Avatar Hierarchy Standard [8] was used for the joint hierarchy (with one change as detailed below). The Standard details a complete hierarchy of human joints as well as highlighting the minimum number of joints that can be used.

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For the purposes of this project, only the minimum required joints were used plus a few additional ones (figure 3) such as vt1 -spinal joint at the top of the torso- left and right sternoclavicular (indicated as l_sterno and r_sterno on the diagram) and the eye joint.

In the H-Anim standard the root-joint, as the name implies, is the root of the hierarchy. However, keeping to this would have meant that to make the avatar lean from the waist to the side a complicated succession of rotations would have been required. The initial rotation of the ‘waist’, i.e. the root joint, to the side would have rotated the whole body about the z-axis lifting the feet off the floor. Due to this, compensatory rotations of the hip joints would then have been required to bring the legs back down again.

In order to avoid this problem the sacroiliac (pelvic joint) was used as the root joint. In this way to make the avatar bend at the waist only the root needed to be rotated and no compensatory movement of the legs was required.

4.1.2 Implementation of Avatar Hierarchy

The drawing and internal structure of the environment and avatars rested on some “classes” that were created to define the primitive triangles used in drawing. A Triangle class was created to hold details for each triangle used in the scene and the avatars. Within the class three instances of a Vertex class held information on the x, y, z positions of each of the three vertices that defined the triangle. A draw method within the Triangle class was defined so that it could be called in order to draw a particular triangle with a colour defined by the Color class.

Two classes were created to hold information on the pieces that made up the avatars:

1. The Segment class held details of the triangles that made up body segments such as the skull or torso.
2. The Joint class held details of the triangles used to make up the joints (e.g. hip joint or wrist joint), the x, y and z positions of the joint, the x, y and z rotation of the joint, the Joint’s children and the segment attached to the joint.

Two data files were read in for each avatar by using the avatar class method *create* (called from the *init* method in the *cubesApp.cpp* file). The first one contained a list of the segment triangle files used to draw the following body segments of the avatar (left hand side body parts indicated by “l_” and right and side body parts indicated by “r_”):

- l_hand
- skull
- r_collar
- r_calf

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-
- l_lowerarm
 - l_upperarm
 - l_collar
 - neck
 - torso
 - r_hand
 - r_lowerarm
 - r_upperarm
 - l_thigh
 - l_calf
 - l_foot
 - r_thigh
 - r_foot
 - pelvis
 - eyes
 - eyelid

The second data file contained details of the triangle files used to draw the avatar's joints and also the x,y,z position of the joint relative to its parent. The files were tab delimited with each line representing a joint and each line having the following format:

Joint_file x_position y_position z_position

The following joints were contained in each file:

- skullbase
- vt1
- l_wrist
- l_elbow
- l_shoulder
- l_sterno
- r_wrist
- r_elbow
- r_shoulder
- r_sterno
- l_ankle
- l_knee
- l_hip
- r_ankle
- r_knee
- r_hip
- root
- sacroiliac
- eyejoint

The Triangle files contained nine space-delineated floating point numbers, corresponding to the x, y, z positions of each of the three vertices, and a hexadecimal number defining the colour e.g. 0x0000AA, mid blue. The numbers were easily assigned to the relevant vertex. However, the colour had to be processed further to convert it to three numbers between 0 and 255 for the red, green and blue components. Prior to the conversion (performed by the method *hexdec*) the number had to be checked as AC3D will output any number that is preceded by zeros as only the non-zero part e.g. 0x0 instead of 0x000000 and 0x1AC4 instead of 0x001aC4. This error catching was performed by the *checkhex* method.

Description of the Avatars

As mentioned, there were seven avatars within the bar environment four female and three male avatars. The avatars were designed to be from different races as it was important to reflect the variety of people in society. In the main group of four there were the following key avatars:

- Tim who was a blond Caucasian man sitting on a high stool at a table leaning slightly to the side with a pint in his hand as if slightly drunk. If asked his name he slurred his words a little and said that he was not feeling very well.

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- May, a red-haired Caucasian female avatar, leaning on the table next to Tim. She had long hair and a glass of wine in her hand. She was designed to be quite uninterested in the Subject of the experiment and would look around herself a lot.
- Bob, a dark-haired Caucasian man with a goatee, was standing next to May with a pint in his left hand, which he would drink with a slurping noise when the “D” key was pressed. He also could put out his hand to be shaken and looked around vaguely.
- Zoë, a dark-haired Caucasian lady was next to Bob and could look around in a disinterested fashion. She was the most impolite as she could walk off to the bar saying in a sarcastic tone “Riveting...I’m off to the bar!”

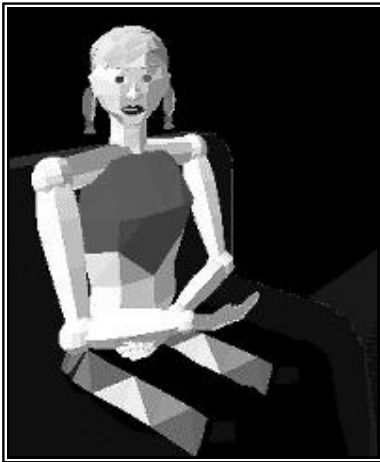


Figure 4: Ami Sitting Down

At the bar was Ben, an Afro-Caribbean barman who could nod politely if the subject spoke to him. He did not have any set phrases to speak as the subjects were meant to talk with the group of people. However, if a subject were to talk to him one of the male phrases could be spoken but with the aim of making the subject return to the group of people.

There were two other female avatars in the environment that were sitting on sofas at a table in the opposite corner to the bar. Lei, an Asian female avatar and Ami a blonde Caucasian avatar. Neither were animated or programmed to say anything, as they were only there to add visual realism to the scene.

Positioning the Avatars

After creating an avatar, its joints were translated and rotated to move it into the required initial position. For the three avatars sitting down it was straightforward to get the legs in the correct positions as it required rotations of the hips in one direction and the knees by approximately the same amount in the opposite direction. However, to rotate the arms to the desired ‘casual’ positions was less straightforward as parts of the arms intersected other body parts unless the precise rotations were found (figure 4).

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Tim, the male avatar sitting on a stool was posed with his torso at an angle as if slightly inebriated and had his arms crossed in an unfriendly posture.

The general positions for the avatars' arms were found by the author observing people. Modifications were then made until the desired result was obtained.

The initial poses for Zoë and Ben (barman) were simple, as they were just standing at an angle. Ben also had his arms angled slightly to look less formal.



Figure 5: Initial Poses for May, Bob and Zoë

May was positioned so that she was casually leaning on the tall table that Tim was sitting at, with a glass of wine in her right hand. Bob was posed standing with a pint of beer in his left hand (figure 5).

First Implementation of the Hierarchy

The resolution in AC3D is denoted in metres, therefore it was possible to know in advance how large the objects would appear in the Cave. Originally the positions of the joints were given as absolute. For example, the pelvic joint (sacroiliac) was positioned at 0.0 in the x and z directions and at about 1.0 metres in the y-direction and the neck joint (vt1) positioned at about 1.5 metres.

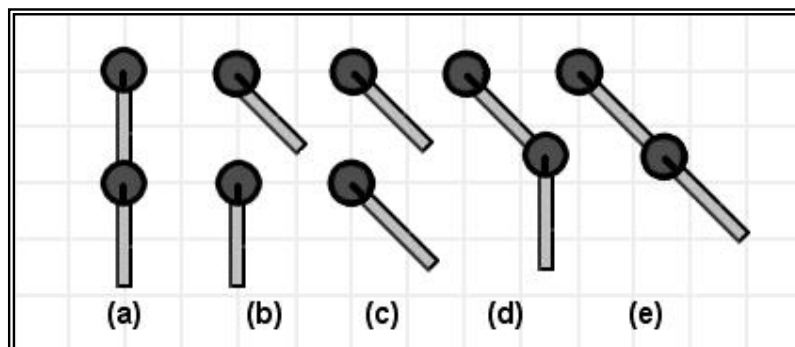


Figure 6: Joint Rotation

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Each joint object held details of its own orientation that was *independent* of its parent. Due to this structure, the method used to rotate a joint had to calculate the new position of each of the joint's children and their children etc. so that changes in position and orientation were propagated throughout the skeleton. If the rotations were not propagated through the children the avatar joints and segments would break up as shown in figure 6b. It is possible to see that the top joint is rotated from its original orientation in figure 6a to that in 6b, leaving the lower joint (its child) in the same place. In able to perform rotations, a *rotateJoint* and *rotateChild* method were created in order to propagate rotations through to lower levels in the tree.

The *rotateJoint* method had the degrees of rotation about the x, y and z-axes passed to it. Inside the *rotateJoint* method the joint that was to be rotated had those values added to the current *xRot*, *yRot* and *zRot* object variables. These values could not be simply added to the rotation values of the children as rotation of the parent would require rotation *and* translation of the children otherwise the avatar would come apart as shown in figure 6c.

In order to find the correct position of the child after rotation the child joint was translated back by the distance its parent was from the origin. It was then rotated by the required amount and translated back by the distance the parent was from the origin to yield the result shown in figure 6d. To get the desired result as shown in figure 6e the rotation amount needed to be added onto the child's rotation variables as the segments were drawn in the same direction as the joint that they belong to.

The transformations of translation, rotation, translation were expressed as a matrix using the *preMult* matrix operations that VR Juggler supports. An iterator was created that iterated through each of the children of the parent and called the *rotateChild* method on the child. The transformation matrix was then passed to *rotateChild* along with the *xRot*, *yRot*, *zRot* variables describing the rotation that was to be done.

Inside *rotateChild* the current position of the joint was multiplied by the transformation matrix and the rotation amounts added on to the child's rotation variables. Another iterator was created inside the method to go through each of the child's children calling the *rotateChild* method on them so that the rotation was propagated throughout the branch of the hierarchy.

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For example, if the right shoulder were to be rotated by 50° about the x-axis then a call to `rotateJoint` would be made by the right shoulder object with the variables 50, 0, 0 to indicate the desired rotations about the x, y and z-axes respectively. Inside the method the rotation amounts would be added to the rotation variables of right shoulder. Then a transformation matrix comprised of a translation of the right shoulder to the origin, rotation of 50° about the x-axis then a translation back to the original position would be created. Each of the right shoulder's children (in this case there is only one child: right elbow) would be iterated through and the `rotateChild` method called. Inside `rotateChild` the current coordinates of the elbow would be multiplied by the transformation matrix and updated accordingly. The elbow rotations would be updated by 50° about the x-axis then `rotateChild` would be called on the right elbow's children. In this case there was just one child, the right wrist.

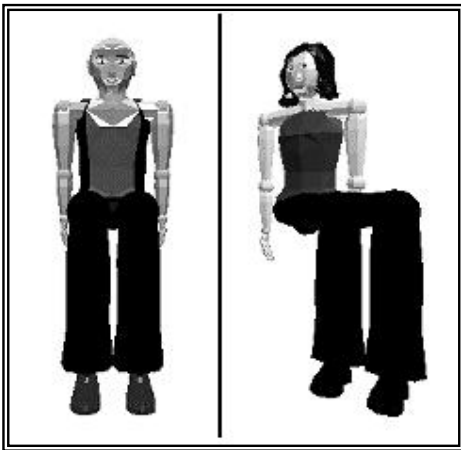


Figure 7: Rotations for Sitting

Problems came with this method when wanting to perform multiple rotations and translations of all or parts of the avatar as the order of the transformations made a huge difference in the result. It made it hard to predict the directions in which the joints needed to be rotated for a specific outcome.

For example to make an avatar sit down a rotation of 90° about the x-axis was required for the hips followed by a rotation of -90° about the x-axis for the knees as shown in figure 7a. However if the avatar was first rotated so instead of facing towards positive z it was facing at 45° then these rotations were no longer about the x-axis, being rotations about the axis created by a line parallel to that made between 1,0,0 and 0,0,1. Clearly, for all but the simplest animations, this made animating unnecessarily complicated.

Figure 7b shows what would happen if rotating the hips by 90° about the x-axis then rotating the knees by -90° about the x-axis after rotating the whole body by 45° about the y-axis. As can be seen the feet are still facing the same way as the body and the legs are twisted away from the direction the body is facing. This was not the desired result. Therefore, the hierarchy was redesigned as detailed below.

Second Implementation of the Hierarchy

The avatar joint hierarchy was re-implemented as a relative hierarchy (figure 8) so that positions and orientations of joints were stored relative to their parent. So, if following the original example given in the first implementation, the pelvis would be at 1.0 metres but the neck would be 0.5 metres *above* the pelvis. To make an avatar sit down, the hips could be bent at 90° about the x-axis and the knees at -90° about the x-axis whatever the general position or orientation of the avatar was. The avatar could be standing on its head and those rotations would still work without having any body parts facing in unexpected orientations.

This made the rotateJoint method much simpler as all that needed to be done was to add the required rotations onto the current ones. The rotateChild method became obsolete as the positions and rotations of the child were relative to its parent so when the parent was rotated the child automatically rotated with it. Propagation of rotations through the hierarchy was no longer necessary.

A *translateJoint* method was also created in order to move the avatar to the required position. The method simply added the translation amount to the joint that had called the method. However, note should be taken that this method should only be called on the sacroiliac joint, otherwise the avatars would become dismembered. A routine where by so called “end-effectors” such as hand and feet could be moved and the body would follow accordingly could have been implemented but it was not deemed necessary for the task.

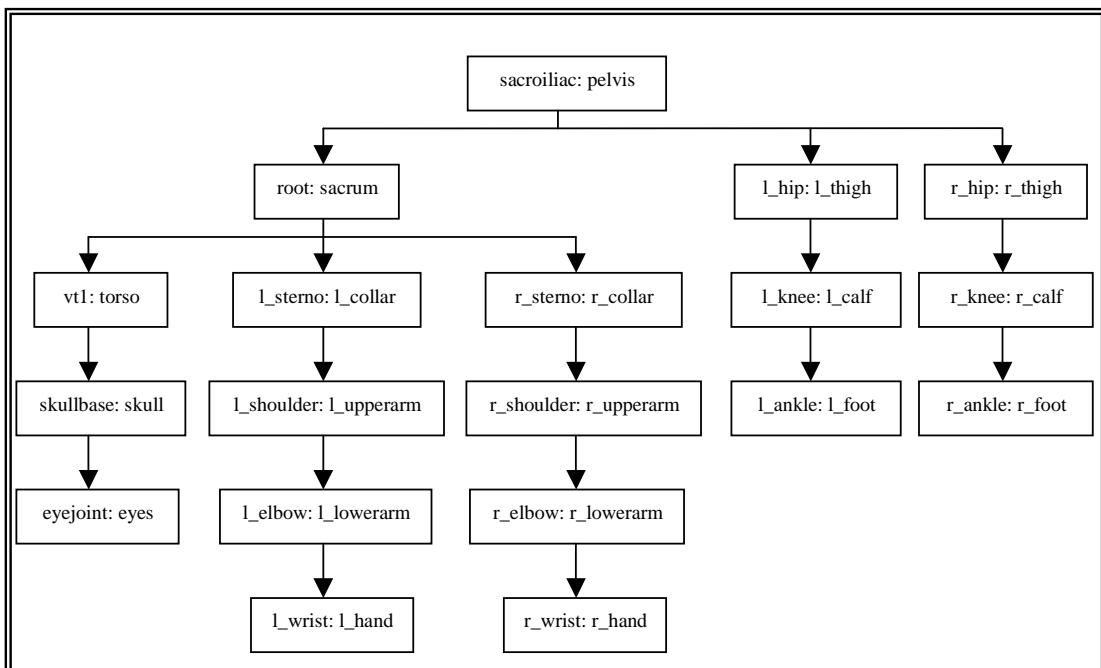


Figure 8: Avatar Joint and Segment Hierarchy

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When drawing the avatar (in the myDraw method in cubesApp.cpp) the joints and segments had to be nested inside the parents with push¹ and pop² operations each side so that relative positions and orientations would take effect. This method simplified the animation process enormously making it much more intuitive and realistic.

The relational hierarchy, taken from the H-Anim standard but with the sacroiliac (pelvic joint) as the root as opposed to the root joint (attached to sacrum), can be seen in the flow diagram in figure 8 with the segment belonging to the joint listed after the colon.

¹ Push: “Pushes” the current orientation and position onto a stack. Everything drawn after this and before the next pop is drawn relative to this position and orientation.

² Pop: Removes all positions and orientations added since the last push operation from the stack.

4.2 Modelling

The skull, the most complex component of the avatar, was constructed by deforming an ellipsoid sphere (figure 9a 9b, vertices shown in blue). This was accomplished by individually moving the vertices of the sphere by first adjusting the vertices whilst viewing in the xy plane and then making further modifications by viewing the skull in the zy plane.

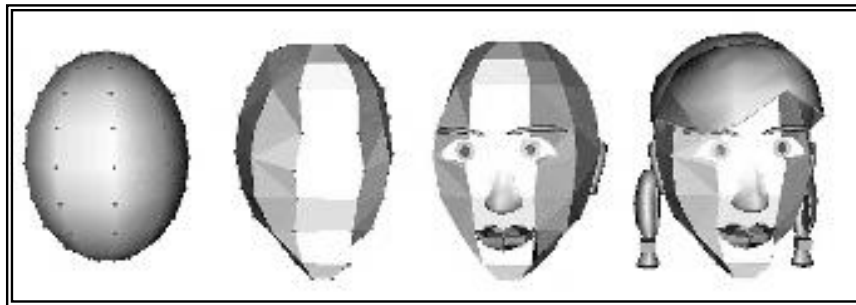


Figure 9: Stages of creating an avatar skull

From one set of body parts that were created, the torsos, eyes and skulls were modified to make individuals (figure 10), as these were the most distinctive segments. Two different sets of arms—one for the female avatars and one for the male avatars were used.

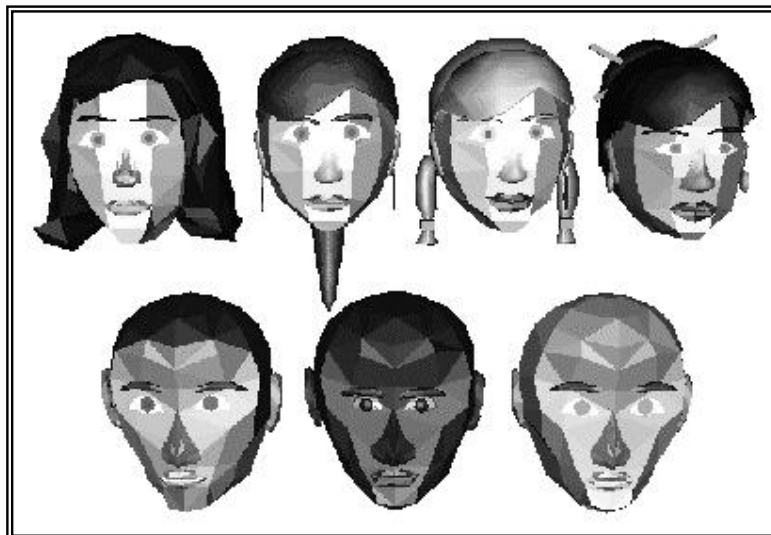


Figure 10: Avatar skulls
Zoë, May, Ami, Lei, Bob, Ben, Tim

The Virtual Wine Bar Experiment

The nose, ears, hair, lips and eyebrows were also constructed using deformed spheres, deleting those triangles that were hidden from view to reduce polygon count. The eyes and earrings were constructed using the polygon tool to create flat shapes that were, in the case of the eyes, bent so that they followed the form of the skull. The hair accessories were created using the box tool.

Creating the avatars using Poser, a 3D modelling package for virtual humans which contains reasonably realistic models of humans, had been experimented with by the author. Although, as can be seen in figure 11a, the skull is much more realistic than the one constructed by hand in AC3D the number of polygons for the head is 12610 instead of 1110 for May's head which is approximately eleven times less. If the Poser models had been used instead of the AC3D ones the polygon count would have been incredibly high as the whole of Ami is only 10818 polygons about 2000 less than that of just the Poser head. The high polygon count may well have slowed down the frame rate in the Cave thus giving a jerky environment which would not help the subject's feeling of presence and may have caused them to feel ill.

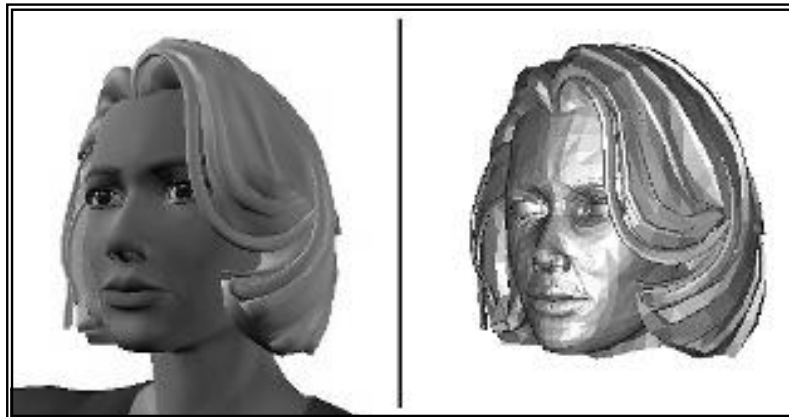


Figure 11: (a) Poser head (b) Poser head imported into AC3D

An additional problem with Poser was that, in order to import the files into AC3D so they could be exported as triangle files, they had to be saved in .3ds format which turned the whole head grey when read into AC3D (figure 11b). In order to colour the face, each set of polygons that was to be the same colour would have to be selected which would have been difficult and time consuming.

4.3 Animating the Avatars

The animations rely on being able to rotate the joints of the avatars and for those rotations to propagate through the children of the joint. Therefore, if, for example, the shoulder joint is moved then not only does the segment attached to it (the upper arm) move but so does the elbow, lower arm, wrist and hand.

As mentioned in §4.1.2, the subroutine `rotateJoint` is responsible for rotating whichever joint it is called by. It was used not only when setting the initial poses of the avatars but also for the animations.

To control the timing of the animation steps, the majority of the animations were done to millisecond timing. However a few of the animations whose timing was not too important (blinking, breathing) were linked to the frame rate.

The time between the different stages in the animations was counted in milliseconds, obtained by a call to the `gettimeofday` function. The `gettimeofday` function gets the current time, expressed as seconds and microseconds since 00:00 Co-ordinated Universal Time, January 1, 1970. A call was made to this function when each avatar was created and the initial amount of seconds was stored in the `init_seconds` variable. Whenever a new animation was triggered another call was made and the seconds deducted off `init_seconds` to give to get the number of seconds at the start of the animation. The number of microseconds since the last second was found and the total number of microseconds since the beginning of the program was calculated. Through some elementary mathematics the number of milliseconds since the start of the program was deduced and stored as `startAnimTime`. Milliseconds were used instead of microseconds as the timing did not need to be that exact as the frame rate was no faster than a millisecond and so a smaller number was easier to work with.

For each frame, if an animation was active, the current time was obtained again and the number of microseconds since the start of the animation were found (by finding the number since the start of the program and subtracting from `startAnimTime`) and stored as `currAnimTime`. In this way tests could be set up within a particular animation method to say, for example, if the `currAnimTime` is between 0 and 500 milliseconds turn the avatar 90° or if between 500 and 1000 milliseconds turn its arm 45°.

4.3.1 Triggering Animations and Sound Clips

Primarily the avatars were static except when performing one of the scripted animations. Since they made none of the small movements that real people do such as twitch, blink or breathe they looked very doll-like and unrealistic. It was decided that adding small animations such as blinking and breathing to each avatar would increase the realism of the avatars tremendously and therefore, hopefully, make the subjects react more naturally to them.

In order to make the avatars appear to blink a “switch” variable was set which was determined by a random number called every frame. If the current blink switch for the avatar was 0 and the random number modulo 100 was greater than 92 then the blink switch was set to 2. If the blink switch was greater than 0 then it was decreased by 1 such that each blink lasted two frames. When drawing the avatar a check would be made on the blink switch, if it was 0 then the normal open eyes were drawn else the closed eyelids were drawn (figure 12). In this way, all of the avatars blinked occasionally but at different times, as would happen in real life.

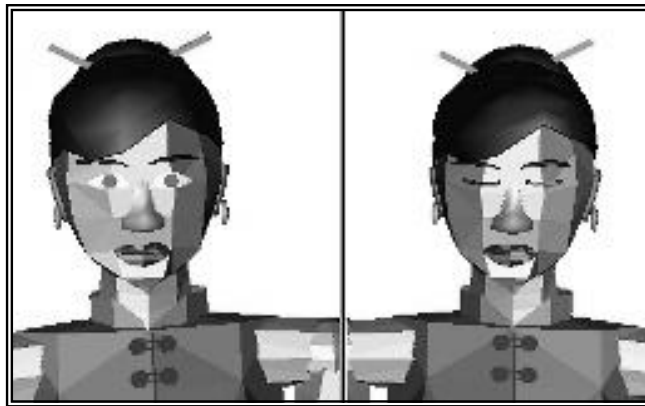


Figure 12: Lei blinking

All of the avatars breathed at different rates, as set in the initialisation method to the avatar *breathe* variable. To make the avatars breathe, a global variable was set that was increased by one every frame. When in the drawing method a check was made and if the variable modulo *breathe* was between 0 and 6 then a slight scale and translation was applied to the torso to make the chest look like it was breathing in otherwise the torso was drawn as usual. As, when people breathe just their chest expands out, the torso had to be translated after scaling so that the back of the torso remained in the same position.

4.3.2 Walking

Walking is something that we take for granted. It is only when trying to break down the motion into its component parts that we start to realise its complexity. It is not just a case of the legs moving; it encompasses rotations in order to simulate walking, by the avatars, of the following joints: left hip, right hip, left knee, right knee, left ankle, right ankle, left shoulder, right shoulder, left elbow, right elbow. If using a more complex skeleton, movement of the joints within the foot would also be incorporated.

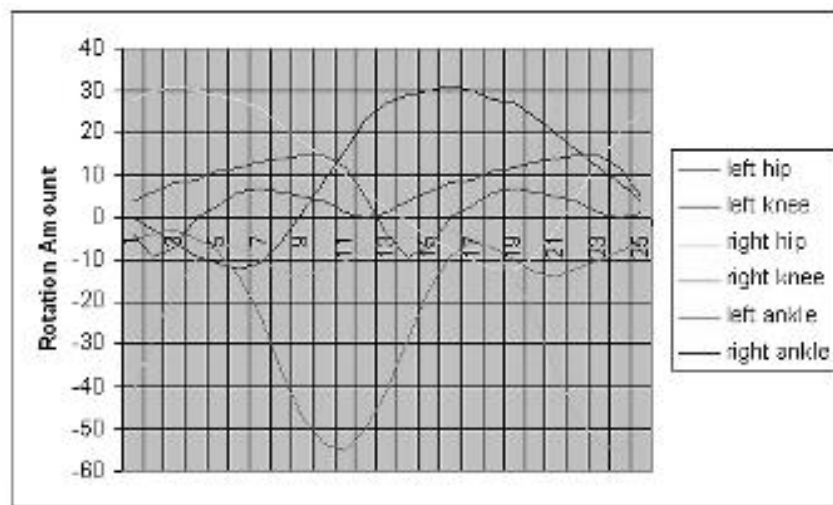


Figure 13: Joint rotations for walking animation

In its most basic form the same set of rotations (figure 13) are repeated to form the walking motion. In its more complex and realistic form the set of rotations are not looped, as the person concerned will change direction for various reasons or ascend/descend the terrain thus contributing to a non-‘predictable’ gait.

However, for the purposes of this project only two step cycles are required in order to let the avatar leave the group and walk to the bar. As the path from the group to the bar is clear and the floor is flat, a direct path could be used.

The complexity used for the animation could have been any degree of realism from simply moving the hip joints in an asynchronous pendulum motion to incorporating inverse kinematics[9]. It was decided that the level of realism of the animation would reflect that of the appearance of the avatars: neither completely basic nor photo-realistic.

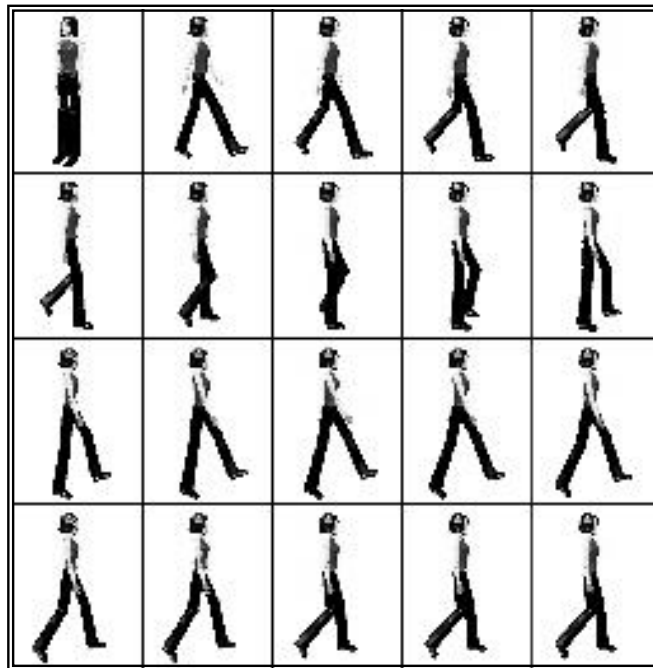


Figure 14: First 20 moves of Walking Animation

The model used was based on the rotations described by Paul Flavin [10] for the ankles, knees and hips. The rotations for the shoulders were derived from the author watching people walking. It was discovered that the elbows move very little during a normal gait and thus were fixed at a constant incline of 10° about the x-axis. A 'speed' for the animation was set which controlled how long each time frame of the animation was to take. 25 stages were used for the gait reduced from the original 50 as detailed by Flavin. The right hand side of the body had the same stages but at a different starting point. The first twenty stages of the walking animation can be seen in figure 14.

4.3.3 Drinking

The drinking action was more complicated than was first envisaged as the rotations of shoulder and elbow had to be precisely calibrated so that the glass reached the avatar's lips rather than being thrown over its shoulder, up its nose or down its top. Only one movement was used to bring the drink to the avatar's mouth which was then kept there for a couple of hundred milliseconds whilst a slurping sound was played then returned to the original position. Rotations were required in both x and z directions and were based on observations with the final values used obtained through trial and error.

This animation could be used impolitely i.e. if someone asked the avatar a question, the avatar could ignore them and drink instead. Otherwise it could be used innocuously as a general action that would happen inside a bar.

4.3.4 Shrugging

This animation was used as it can be used impolitely to indicate indifference, depending on the context. The shrugging motion entailed rotating the shoulders towards the neck and rotating the elbows the same amount in the opposite direction to compensate otherwise the avatar would look like they were flapping their arms. This was simply a two-stage animation: lift shoulders and lower shoulders.

4.3.5 Nodding

This was the most basic animation involving two stages and only one rotation, that of the skull base, at each stage: one to rotate the skull forwards and one to return it to its original position.

The nodding animation was used for the barman to acknowledge someone at the bar.

4.3.6 Looking Around Vacantly

An action that people often do, either consciously or unconsciously, when bored is to look around them as if to try and find something more interesting to focus their attention on. Therefore, an animation whereby May, Bob or Zoë (the three avatars that were in the group and standing up) could look vacantly around them was incorporated into the experiment (figure 15).

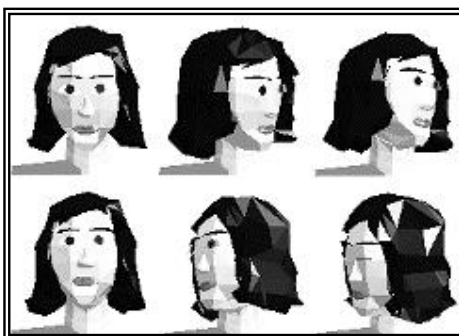


Figure 15: Looking around animation

movements where the skull base was rotated to look left (45° about y-axis), right (-45° about y-axis), right again (-45° about y-axis), and back to normal (45° about y-axis). Upon pressing the button, the avatar slowly looked around them as if bored.

4.3.7 Hand Shaking

In order to help find out whether or not people react to avatars in a virtual environment as they would to real people, an animation was created whereby Bob could put out his arm as if to shake someone's hand. This required a rotation of the shoulder by -15° about the x-axis and the elbow by -70° about the x-axis. Upon pressing the same key that was used to trigger the arm going out, the arm was withdrawn.

5 Experiment Design

5.1 Subject Selection

The subjects for the experiments were taken from the student body at University College London. The criteria for recruitment was not strict as the subjects were not being paid. It was hoped that the randomness of the selection procedure would lead to a mixture in the level of social anxiety that the subjects had.

Ten people were used for the experiments including one who was used as a pilot sample to check that the methods that were to be employed worked sufficiently.

The subjects were by chance an even split of five females and five males thus giving another basis for evaluation.

5.2 Experiment Timing

The number of subjects was the maximum that could be fitted into the allotted CAVE time of two mornings. It had been thought that more subjects would be used. However, after the initial pilot experiment it was clear that the total time for subjects to go through the two experiments and fill in the questionnaires would take longer than first envisaged (approximately 30 minutes as opposed to the 15-20 that had been predicted).

Time had been set aside at the beginning of each morning to make sure the system was running correctly. This proved to be fortuitous as it was found on the first morning that the head tracker had broken and so a makeshift one had been created from the hand tracker. This meant that the code for the underground train scenario had to be changed in order to be compatible with the hand tracker instead of the head tracker.

On the second morning a new head tracker had been installed and there were discrepancies between where it was reporting to be in the CAVE and where it actually was. However, this was fixed before the first subject arrived so did not delay the experiments.

5.3 Procedure

The subject was to be welcomed then asked to read an information sheet and fill in a consent form. Following this they were asked to fill in a background questionnaire, Questionnaire A¹, in order to provide key information that could be relevant to the study.

The subject was then asked to remove their shoes by the author (in order to protect the floor screen of the CAVE) then they were given a brief introduction to the CAVE and the equipment that was to be used: *“This is the CAVE. An environment will be projected on the three walls and floor. These glasses”* (hand them the stereo glasses) *“will enable you to see the environment in 3D. This is a head-tracker”* (help them put on the head tracker) *“which lets the program know where you are in the CAVE”*.

The two parts to the experiment involved the subject going into an underground train environment (designed by Chien-Yu Lin) and going into a bar environment (as described in the previous few chapters and as designed by the author).

The subject was then told what the experiment entailed. Each subject was told roughly the same thing about the experiment to make sure that no bias could occur from some subjects knowing more than others did.

- Bar experiment: *“When the program starts you will find yourself in a bar. In front of you there will be a group of people. Please go up to them and start a conversation.”*
- Underground train experiment (1): *“You are travelling by tube to a bar. Enjoy the tube!”*
- Underground train experiment (2): *“The second experiment is that after the bar you need to go home so you travel by tube. Enjoy the tube!”*

Half of the subjects performed the train experiment first and then the bar scenario (underground train experiment (1)), as if taking the underground train to the bar. The other five performed the experiments the other way round, as if travelling home by underground train from the bar (underground train experiment (2)).

¹ Appendix B

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After letting the subjects know their task they were asked if they understood what they had been asked to do. If not then the instructions to the task were repeated. They were also told that if at any time they wanted to leave the experiment (for example if it was distressing them) then they must say and the program would be stopped. The program was then run.

At the end of the experiment the subject was asked to fill in Questionnaire B. On completion of the questionnaire the subject was taken back to the CAVE where they performed the second experiment. At the end of the experiment the subject was then asked to fill in Questionnaire B again, this time bearing reference to the second experiment. Once this had also been completed the subject was asked if they minded taking part in a short interview conducted by the author and Chien-Yu. If they agreed then a short interview was conducted and also recorded on mini-disc (if this was acceptable by the subject).

5.4 Questionnaires

The main purpose of the questionnaires was to determine the subject's Social Avoidance and Distress (SAD)[11] response before the experiments, i.e. their usual level of social anxiety, and afterwards i.e. their level of social anxiety during and after the experiments. Other information was also gained from the questionnaires; both questionnaires are explained in greater detail below.

5.4.1 Questionnaire A (Pre-Experiment Questionnaire)

The pre-experiment questionnaire asked pertinent questions about the subject such as:

- Gender (male or female)
- Status (e.g. undergraduate, postgraduate, staff etc)
- Previous experience of virtual reality (on a scale from 1[never before] to 7[a great deal])
- How much they use a computer on a daily basis (on a scale from 1[not at all] to 7[very much so]).

Also, the questionnaire was used to help determine the subject's general level of Social Avoidance and Distress (pre-experiment SAD score) by giving twenty-seven statements about social situations to which they had to agree or disagree. Examples of these are as follows:

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1	I feel relaxed in unfamiliar surroundings
2	I often find social settings upsetting
3	I try to avoid talking to people unless I know them well
4	I usually feel relaxed when I meet someone for the first time
5	I often think up excuses in order to avoid social engagements

Their pre-experiment SAD score could be found by counting up the number of “negative responses”. From the above examples, points would be given for agreeing to 2, 3 and 5 and disagreeing to 1 and 4. As there were twenty-seven statements the SAD score was marked between 0 and 27.

5.4.2 Questionnaire B (Post-Experiment Questionnaire)

The first ten questions on questionnaire B are divisible into questions on “co-presence” (how much the subject felt they were *with people*) and “social phobia”. All were to be answered on a scale of one to seven.

The co-presence questions were as follows:

Question No.	Question	Answer scale
3	How much did you have the sense that there were people in the situation with you?	Not at all τ Very much
4	How much did you have a sense of talking to other people?	Not at all τ Very much
5	Was it more like talking to a computer or communicating with people?	Like a computer τ An audience
6	How aware were you of the people?	Not at all aware τ Very aware

The social phobia related questions were as follows:

Question No.	Question	Answer scale
1	How comfortable and relaxed did you feel with the people?	Not at all comfortable and relaxed τ Very comfortable and relaxed
2	How pleased were you with the way you responded to the people?	Not at all pleased τ Very pleased
7	What sort of impression do you think you made	Very negative impression τ Very

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	on them?	positive impression
8	How friendly were they?	Very unfriendly τ Very friendly
9	How interested were they in what you had to say?	Not at all interested τ Very interested
10	How much would you like to meet with them again?	Not at all τ Very much

They were also asked to give a rating out of a hundred for their social performance. Additionally they were asked to answer yes or no to whether or not they experienced any of the following nine signs of discomfort during the experiment:

Sweating (clammy palms, perspiration)
Discomfort in the stomach (butterflies)
Heart Palpitations
Tremors (shakiness)
Nerves/ Feeling of being scared
Tightness in chest
Tenseness
Loss of balance
Nausea

The next set of questions contained twenty-seven statements about how the subject felt in the social setting experienced in the virtual environment. The subject could either respond with a yes or no to these statements to indicate their agreement. The purpose of these statements was to gain an indication of the level of Social Avoidance and Distress experienced during the experiment (post-experiment SAD score). The set of statements included the following (the complete questionnaire can be found in Appendix D):

1	I wanted to avoid the situation
2	It was not easy for me to relax with those strangers
3	I took the chance to meet new people
4	I often wanted to get away from those people
5	Having to introduce myself made me tense and nervous

As with Questionnaire A, the post-experiment SAD score was gained by counting up the number of “negative responses” from the statements. In the above example marks would be given for agreeing to statements 1, 2, 4 and 5 and for disagreeing to statement 3.

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The last three questions on the questionnaire were open-ended:

- What were the best things about your encounter with the other people?
- What were the worst things?
- Please add any other comments about your experience.

The purpose of these questions was to find out any additional information that could help in the improvement of the experiment, and also to gain a greater insight into how the subjects reacted to the experiment.

5.5 Experiment Purpose

The main purpose of the experiment was to try to find out whether or not people react the same in a virtual environment as they would in the “real world”. Furthermore, do they react to avatars (virtual people) in the way they would react to real people irrespective of the realism of the avatars? The implication of this experiment, should it indicate that people *do* behave in virtual environments as they would in the real world and they *do* interact with avatars as they would real people, is that virtual reality could be used in order to help treat people with social phobia.

Performing half of the experiments with the bar scenario first and half with the underground train scenario first meant that the results could be interpreted in the following ways:

- If the second experiment was influenced by the first then the second experiment could be discounted and there would still be five people who had performed the bar experiment and five who had performed the underground train experiment. Also additional information could be possibly be gleaned.
- If the first experiment did not influence the second then there were ten who had done each scenario (including the pilot).

The following questions aim to be answered from the data gained in the experiments:

- (1) Does the subject’s level of social anxiety (SAD score) relate to their feeling of co-presence in the environment(s)?
 - (2) Does the subject’s social avoidance and distress score relate to the anxiety felt during and after the experiments?
 - (3) Does gender affect discomfort or co-presence?
 - (4) Does the amount of experience the subject has of virtual reality affect their feeling of co-presence in the environment?
 - (5) Does the amount the subject uses a computer on a daily basis effect their level of anxiety?
-

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- (6) Is the subject's level of anxiety and co-presence different in the first scenario (wine bar or underground train) to the second?
- (7) Is the subject's level of anxiety and co-presence greater in the wine bar virtual environment than in the underground train?
- (8) Is the subject's SAD score related to their level of discomfort (sweating, shaking etc) during the experiments?

5.6 Hypotheses

The following are a number of hypotheses about the results that will be gained from the experiments:

1. Subjects will, in general, be more relaxed in the second scenario as they will have a better idea of what to expect from the experiment.
2. Subjects are likely to feel more discomfort in the bar scenario than in the underground train scenario as
 - (a) The task set is more daunting- they *have* to talk with the avatars as this is part of their brief.
 - (b) The avatars are designed to be impolite to the participant in both their gestures and their manner of speech.
3. Subjects that have had little or no experience of virtual reality are more likely to have a greater feeling of co-presence in the virtual environments as they will be more concerned with the new experience than with the quality of the computer graphics etc.
4. The greater the subject's level of social anxiety, the greater will be their level of discomfort in the experiments.
5. During gaps in conversation, if the subject is socially phobic they will show anxiety, thinking that the avatars are not interested in them. However, if the subject is confident and not socially phobic then they will be more likely to speak to the avatars in an attempt to elicit information from them

6 Experiment

6.1 Scenarios

There were two parts to the experiment, a bar scenario (the construction of which has been detailed in the preceding chapters) and an underground train scenario as constructed by the author's colleague Chien-Yu Lin. The story line linking the two scenarios being that the subject was either travelling to or from the bar by train.

The underground train scenario was a neutral environment with avatars standing and sitting in the train. When the subject was in the scene the avatars acted in a neutral manner; with one of them reading a book, one nodding off to sleep and one looking at the user. If the subject went to the sitting area of the train an avatar attempted to halt their motion by waving their arm in front of the subject and asking how to get to Chinatown. This was to avoid the situation of the subject possibly attempting to sit down in the environment, which is not possible, as they would just fall over due to there being no real seat.

In the bar experiment, the user was inside a bar populated by a number of avatars: a barman, two women sitting down and a group of four (two women and two men) with one sitting at a high table and the other three grouped nearby.

6.2 Experiment Procedure



Figure 16: Initial view of the bar

When the program started up the subject had a view of the bar (figure 16) with a group of four people (two men and two women) in front of them, the bar and barman to their right and two more people behind them sitting on sofas.

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The subject was then left to act and react as they pleased within the Cave. They had been asked to talk to the group of avatars but this was just an instruction, they could actually, if they so desired, go anywhere inside or outside the virtual bar.

There were certain animations and phrases that were always triggered by the author when the subject was in the cave. When exactly these were played depended on the behaviour of the subject and what the subject was saying. For example, if the subject asked if one of the avatars would like a drink the “whatever” sound clip could be played, which would sound very impolite as it is said in a sarcastic tone.

Key	Animation	Key CTRL +	Female Voice	Key SHIFT +	Male Voice
N	Ben (Barman): Nod	A	“Hi”	A	“Fascinating”
D	Bob: Drink pint	B	“Nice to meet you”	B	“My name’s Bob”
H	Bob: Handshake	C	“Really”	C	“Gee, you really do lead a fascinating life”
X	Bob: Look around vacantly	D	“Fascinating”	D	*laugh*
V	May: Look around vacantly	E	“Mm hmm”	E	“Hmm. Nice to meet you”
τ	May: Move head left	F	“Yeah, yeah”	F	“Oh, really”
μ	May: Move head up	G	“Whatever”	G	*slurp*
ρ	May: Move head right	H	“Riveting. I’m off to the bar”	H	“Really... tell me more”
o	May: Move head down	M	“I am May”	I	“Uh huh”
S	Tim: Shrug	Z	“I am Zoë”	J	“Oh is that the time? I really must be going”
W	Zoë: Walk to bar			K	“Yeah. Yeah”
Y	Zoë: Look around vacantly			T	“Errggghhh... My name’s Tim... I’m really not feeling very well”

Figure 17: Table of keys used to trigger animations and voice clips

The animations that could be activated by the author were Bob drinking a pint, Bob putting out his hand for the subject to shake, May, Bob or Zoë looking vacantly around, May rotating her head, Zoë walking off to the bar and Tim shrugging. All of the avatars blinked and breathed at different rates as determined when they were created. A number of audio wave clips of a male and female voice were played when certain keys were pressed. Figure 17 details which keys and key combinations were used to trigger which animations and audio files.

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After approximately two minutes the audio clip “Oh, is that the time? I really must be going!” was played. The subject was told that it was the end of the experiment and that the program would end. After the experiment the subject was asked if they were all right and a second questionnaire (Appendix D) was given them to fill in. The second experiment was run along the same lines as the preceding one (in half the cases the bar scenario was played before the underground train scenario and in the other half of cases it was the other way round).

After both experiments had been performed and the questionnaires completed the subject was asked if they would mind being given a brief interview. If they agreed then the author and Chien-Yu Lin carried out the interview and recorded it if consent given; otherwise the majority of answers were transcribed. During the interview questions were asked to further determine the subject’s reaction to the environments such as “How did you feel when the avatars looked at you?”.

7 Results

The results were gained by analysing the questionnaires that the subjects filled in pre- and post-experiments and also by monitoring the participants during the experiments by watching and audio-recording them to see and hear their reactions whilst in the virtual environments.

7.1 Qualitative Results

The subjects interacted with the virtual environments and avatars with varying degrees of natural behaviour. The findings from each of the subjects are detailed below.

7.1.1 Subject #1

Subject #1 (the pilot subject) had the second highest social anxiety rating prior to the experiments. During the first experiment (underground train) he experienced two signs of discomfort: Nerves/feeling of being scared and a feeling of tenseness. These feelings were not apparent for the second experiment, most probably because he had a better idea of what was going to happen. A problem that he identified in the interview was that he could not tell who was talking to him and had problems hearing what they were saying. This appeared to cause some confusion and probably contributed to his discomfort.

7.1.2 Subject #2

Subject #2 had a high level of previous virtual reality experience (5 out of 7), joint highest with subject #6. In the interview she was the most critical about the environment, out of all of the subjects, possibly because she had had a high level of previous exposure to virtual reality. When asked what she thought of the experiment she replied “*..the bar? I didn't really have the feeling of a very real situation... cause first of all when you go to a bar you don't go directly to the people. So in the moment you ask us to go directly it isn't very real... and also you don't have a proper conversation*”. This was a valid point as it would be very unlikely that one would go into a bar and directly go to a group of strangers and talk to them without a reason. Interestingly, she was the only subject to make this point as, potentially due to her high exposure to virtual reality, she could look beyond the technology to what was actually happening in the experiment. This has implications for further experiments that great care should be taken to make the scenarios as real as possible from the start of the experiment.

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Conversely she remarked that the underground train was more realistic as people do not usually talk to you unless you are with friends. However, her feeling of reality was broken in the underground train “... *the girl was asking me to go er, I don't know where. She asked that like six times and gives you the feeling is she really interested or is she stuck with the question?*”

She also commented that the absence of background noise detracted from the reality of the wine bar environment. This was a point that had been thought through by the author and is discussed further in section 8.2.

7.1.3 Subject #3

Subject #3, who had a very low prior SAD score of 1, indicating a confident person who is at ease interacting with people, reacted in a very natural way with the avatars and when Bob put out his hand in the bar scenario she went to shake it. Also when Zoë stated that she was going to the bar and walked off, the subject said, “Can I go with you? Hehe... hehe” and walked alongside Zoë. Subject #3 talked to the avatars as if they were real people that she had just met saying that she was at UCL doing a PhD and asking them what they were doing. She also stated at the end of the bar experiment that she “Did not like her” (referring to Zoë) as Zoë replied “Whatever” in a sarcastic tone to the question “Hi, how are you?”. She said in the interview afterwards that she tried to “be” in the environment despite knowing that it was not real. This statement reinforced her behaviour in the Cave as she did indeed act and react as if it was a real situation.

Subject #3's experience of the bar scenario influenced her perception of how the avatars would react in the underground train scenario. This was apparent as she stated that the person in the train that asked for directions was rude because when she replied with directions, the avatar didn't say thanks. The subject was expecting the same level of interaction in the underground train as there was in the bar i.e. that the avatars would speak back. However, this was not the case in the train scenario as the avatar that asked how to get to Chinatown spoke only when the subject crossed a certain point in the train. This indicates that a person's expectations in the Cave are influenced by recent previous experiences in virtual environments. This could be an important point when designing environments to help treat people with social phobia as these preconceptions could be an advantage or disadvantage depending on the desired response.

7.1.4 Subject #4

The post-experiment SAD scores (6 for the underground train scenario and 1 for the bar scenario) for subject #4 were both lower than their pre-experiment SAD score (11). He commented in the interview, when asked what the experiment felt like: *“More like computer games really isn’t it?! I know they’re not real”*. The post-experiment SAD scores could perhaps be attributed to this; he was treating the experience as a computer game and therefore had few feelings of anxiety. Additionally, he showed no signs of discomfort (such as nausea or sweating) during either scenario, further emphasising his low level of anxiety.

7.1.5 Subject #5

Subject #5 had the highest Social Avoidance and Distress score out of all of the subjects: 17 out of a possible 27 (63%). She also used a computer least, out of all the subjects, on a daily basis. Her social anxiety must have been fairly acute as she rated her social performance very low out of a possible 100: 3 for the bar experiment and 1 for the underground train. In comparison with the other subjects these low scores are amplified further as the lowest any other subject put was 20 (subject #1 for the underground train experiment).

Her anxiety increased from 17 in both scenarios to 18 (67%) in the underground train and 22(81%) in the bar (the highest post-experiment SAD score). In the underground train it was possible to see her getting stressed when the girl kept asking how to get to Chinatown.

In the wine bar she asked a question to the avatars *“Excuse me, I am searching for a friend Andy. Do you know where he might be?”*. By asking a question she was giving herself a purpose in making conversation. She had not been briefed with a purpose, perhaps it helped her when going up to the strangers to have a reason. If they had replied *“No, we don’t know where Andy is”* it would have given her a valid reason to walk away. Instead they replied *“Nice to meet you”* which did not answer her question. The subject did not repeat her question but neither did she go away, most likely because they had, at that point responded in a positive manner.

Subject #5 suffered from the following signs of discomfort during the wine bar scenario: Discomfort in the stomach (butterflies), Heart Palpitations and Tremors (shakiness). In the underground train scenario she suffered from Sweating (clammy palms, perspiration), Heart Palpitations and Tremors (shakiness) and Nerves/ feeling of being scared.

7.1.6 Subject #6

The greatest difference between the two post-experiment SAD scores was shown by subject #6 who had a post-experiment SAD score of 18 for the first scenario (wine bar) and just 1 for the second scenario (underground train).

Subject #6 had the joint highest level of co-presence for the bar scenario (22 or 79%) which was reflected in the way that he answered the open questions at the end of the post-experiment questionnaire. He wrote as if they were real people, not virtual ones: “They didn’t want to know me”. Similarly in the underground train “I was able to provide useful information” (when asked how to get to Chinatown). These comments indicate that he found the bar scenario to be an unpleasant experience compared to that of the underground train. The subject exhibiting three different signs of discomfort in the bar scenario (sweating, nerves, tenseness) and none in the underground train scenario and having a high SAD score for the bar and a low one for the underground train confirms this.

7.1.7 Subject #7

The pre-experiment SAD score for subject #7 was 7. Her post-experiment SAD score for the underground train decreased to 3 and for the wine bar increased to 15. The increase for the bar is perhaps explained by her comment that it was “*quite strange, in a way I think I felt more uncomfortable because they [the avatars] weren’t real*” and the worst thing about the bar was “*their [the avatars] response*”. It appears that the avatars in the bar made her feel uneasy and she displayed two signs of discomfort in this scenario (sweating and nerves).

7.1.8 Subject #8

Subject #8 remarked to the question “What were the best things about your encounter with the other people?” in Questionnaire B that she “*knew they weren’t real so I didn’t care that we didn’t hit it off*”. This feeling was reflected in her co-presence scores as they were fairly low, less than 40% (39% for the wine bar scenario and 25% for the underground train scenario). However, despite “knowing that the avatars were not real” she still experienced discomfort in both scenarios: three forms of discomfort in the wine bar scenario (discomfort in the stomach (butterflies), nerves/feeling of being scared and tenseness) and one in the underground train scenario (loss of balance). Also her post-experiment SAD score was six points greater than her pre-experiment SAD score for the bar scenario (it stayed the same for the underground train scenario) thus indicating that feelings of anxiety overran her knowledge that the scenarios were not “real”.

7.1.9 Subject #9

Subject #9 commented that the worst thing about the bar scenario was “*Simple answers, often with bad timing*” and that he “*could hear keyboard clicking in the background, like commands were being issued to the avatar. This was distracting and detracted from the feeling of presence*”. These were very interesting comments as they would usually indicate that the subject had a low feeling of presence in this scenario.

However, his co-presence score for the bar was high, at 75% so his feeling of being with other people was high. This indicates that perhaps more extensive measures should be used to measure presence as well as co-presence for example, inclusion of presence related questions or to monitor “breaks in presence”[12]. However, it must be noted that the purpose of this experiment was not to research the subject of presence but to find out whether or not people interact with avatars as they would with “real” people.

7.1.10 Subject #10

Subject #10, along with subject #9 and subject #3, had a very low pre-experiment SAD score of 1. However, despite having such a low level of general social anxiety, his SAD scores increased after both scenarios to 8 for the bar scenario and 7 for the underground train scenario. It appears, from the comments made at the end of the post-experiment questionnaires that he had not found either environment a pleasant experience: “*‘Whatever’. Not very responsive to what I said*” (with respect to the underground train scenario and the female avatar replying “whatever” when he asked her a question), “*She didn’t listen. She was repeating the same question. She wasn’t very friendly*” (with reference to the woman asking how to get to Chinatown in the underground train scenario). Signs of discomfort were only shown in the bar scenario, which was the first experiment. This is most probably because, although he found the people in the underground train scenario unfriendly, he had a better idea of what to expect for the second scenario.

7.2 Quantitative Results

7.2.1 Co-Presence

Questions 3, 4, 5 and 6 in the post-experiment questionnaire relate to the subject's feeling of co-presence¹ in the virtual environment. The method of assessing the subject's level of co-presence was taken to be the sum of the figures given for each of these questions. Therefore as each question could elicit a response of between 1 and 7, the highest potential co-presence mark would be 28 and the lowest 4.

How does the subject's level of social anxiety (SAD score) relate to their feeling of co-presence in the environments?

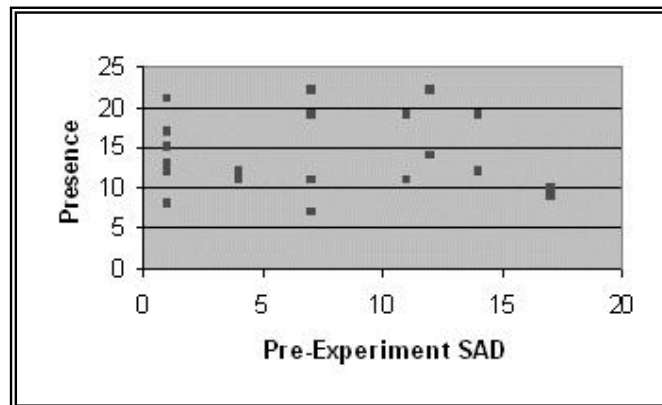


Figure 18: Pre-Experiment SAD vs. Co-Presence

As can be seen from the general results shown in figure 18, there was no correlation between the pre-experiment Social Avoidance and Distress levels and the level of co-presence.

Is the subject's level of co-presence different in the first scenario (wine bar or underground train) than in the second?

Interestingly, the mean level of co-presence was *greater* in the second experiment than the first (14.8 as opposed to 13.6). The possible reason being that in the second scenario they were less nervous as they knew what to expect and could therefore relax. This resulted in them feeling more like they were *with* other people instead of being constantly aware that the avatars were not “real” (this difference is almost certainly not statistically significant).

¹ Presence: The sense of ‘being’ with people

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Is the subject's level of co-presence greater in the wine bar virtual environment than in the underground train?

The three highest co-presence scores were gained in the bar scenario and the two lowest were for the underground train scenario. In fact, seven of the top ten highest co-presence scores were for the bar and the three that were not had high scores for both scenarios. These scores could indicate a correlation between interaction and co-presence as the subjects had little to do in the underground train scenario other than walk around, whereas in the wine bar they had to actively participate and talk to the avatars.

The fact that subject #1 could not tell who was talking and had problems hearing what the avatars were saying would be an expected indication that the feeling of co-presence in the scenarios was low. However, this was not true as the co-presence score for the underground train was 12 (43%) and for the bar 19 (68%), neither being particularly low scores.

Does the amount of experience the subject has of virtual reality affect their feeling of co-presence in the environment?

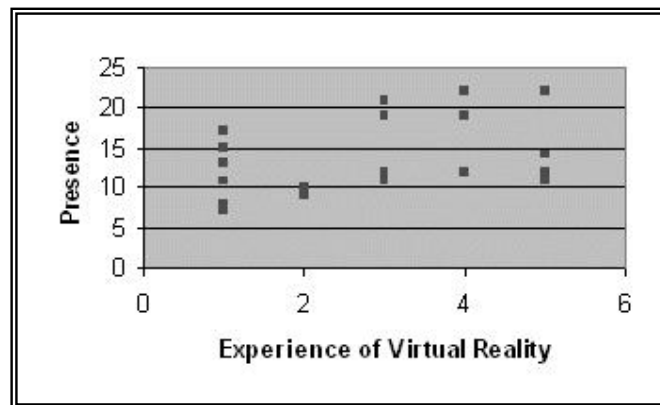


Figure 19: Virtual Reality vs. Co-Presence

The graph plotting experience of virtual reality (1=no experience, 7= a lot of experience) against feeling of co-presence in the virtual environments (figure 19) shows that there is a relationship between the two. The greater the subject's prior experience of virtual reality, the greater their feeling of co-presence in the virtual environments. This is possibly because they can relax more and take part in the experiment instead of wondering if the head tracker will fall off or they will trip up, for example.

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The pre-experiment SAD responses are “*positively and significantly correlated*” [13] with the post-experiment SAD increasing for the wine bar scenario as opposed to the train scenario, and decreasing with the order of the experiment.

7.2.2 Social Avoidance and Distress (SAD) Scores

Is the subject’s level of anxiety different in the first scenario (wine bar or underground train) than in the second?

In the majority of cases (eight out of the ten, including the pilot), the subjects’ after SAD (Social Avoidance and Distress) score was greater for the first experiment than for the second one. This follows the hypothesis made that the subject would be more relaxed for the second experiment than for the first and they would have more of an idea of what to expect having already completed one experiment. This indicates that unfamiliarity of virtual environments contributes to the levels of anxiety felt.

The greatest difference was for subject 6 whose after SAD score for the first experiment (bar) was 18 and for the second experiment (underground train) was 1. In the two cases where the second after SAD score was greater than the first after SAD score the second scenario was the bar, which was designed to be more intimidating (figure 20).

ID	Before SAD	After SAD 1	After SAD 2
(1)	14	14	4
2	4	5	3
3	1	5	1
4	11	6	1
5	17	18	22
6	12	18	1
7	7	3	15
8	7	13	7
9	1	10	8
10	1	8	7

Figure 20: SAD Scores

(Results for bar experiment in red and results for underground train experiment in blue)

Is the subject’s level of anxiety greater in the wine bar virtual environment than in the underground train?

The average after SAD score for the bar experiment was 9.9 and for the underground train it was 7, this follows the hypothesis as the bar scenario was designed to be more stressful and intimidating for the subject whereas the underground train scenario was fairly neutral.

The Virtual Wine Bar Experiment

From figures 20 and 21 it is possible to see that the relationship between a person's social anxiety level and their level of anxiety after the experiments is approximately linear, especially for the first experiment. The results for the second experiment are affected by the first experiment, which would explain why the correlation is less strong for the second experiment scores.

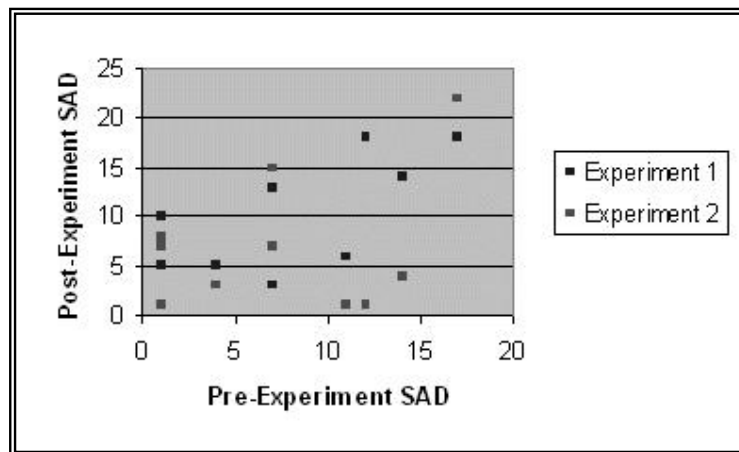


Figure 21: Pre-Experiment SAD Scores vs. Post-Experiment SAD Scores

How does the subject's social avoidance and distress score relate to the anxiety felt during and after the experiments?

The results when segregating by experiment (bar or underground train) are not independent as some are the first experiment and some are the second experiment. The clearest correlation between before and after SAD scores is shown when only the first experiments are taken into account and the results are segregated into the bar and underground train experiment (figure 21).

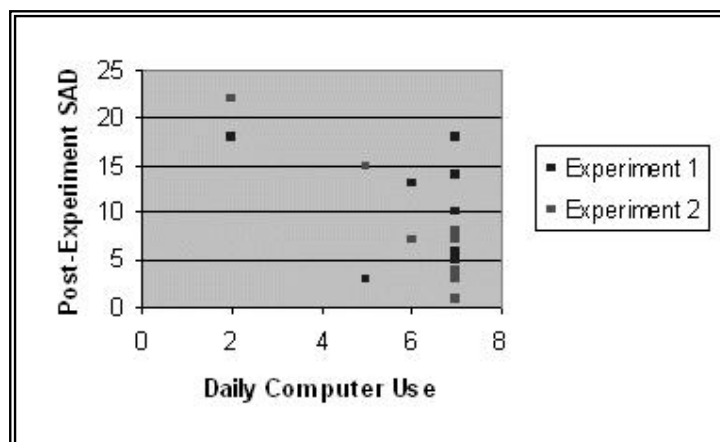


Figure 22: Daily Computer Use vs. Post-Experiment SAD Score

How does the amount that the subject uses a computer on a daily basis affect their anxiety in the virtual environments?

There appears to be little correlation between level of daily computer use and anxiety during the experiments (figure 22). However, the two highest post-experiment SAD scores were obtained by the subject with the lowest daily use of computers indicating that potentially there is a correlation. It is difficult to make a firm conclusion due to the small sample set, with many of the subjects having the same level of daily computer usage.

7.2.3 Discomfort

How is the subject's SAD score related to their level of discomfort (sweating, shaking etc) during the experiments?

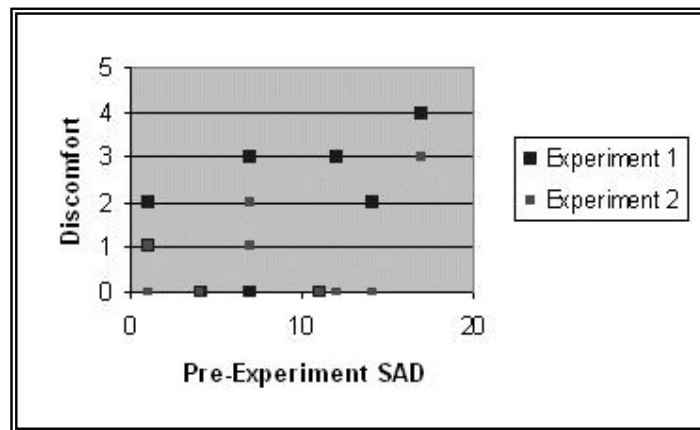


Figure 23: Pre-Experiment SAD vs. Discomfort

For every subject their physical discomfort score for the first experiment was greater than or equal to that for the second experiment (figure 23). This verifies the hypothesis that discomfort will be less for the second experiment than the first as the subjects will have a better idea of what to expect and thus will be more relaxed.

It was found that the post-experiment SAD responses were “*significantly and positively correlated with subjective physiological response [12]*” (the level of discomfort experienced by the subjects). No variable could be removed from the regression model without a significant loss of fit.

7.2.4 Prior Experience of Virtual Reality

When analysing post-experiment SAD responses and the level of discomfort (subjective physiological response) of the subject if the subject's prior experience of virtual reality is taken into account then it is "*significant and is associated with a reduction in anxiety*" [12]. Additionally there is an effect with order as those with greater prior experience and for the second experiment undergo the greatest reduction in anxiety.

7.2.5 Friendliness

The average score given for friendliness of the avatars in the scenarios was 3.8 for the underground train scenario and 3 for the bar scenario. This is a good result as the underground train was designed to be neutral and complete neutral would be 4 as the scale is from 1 to 7. The bar was designed to be less friendly and therefore the score of 3 fits the intended result. However, this is not a concrete conclusion as it was a small sample size.

7.2.6 Gender

There did not appear to be any correlation between gender and co-presence or gender and anxiety/discomfort. However, more extensive studies would have to be made in order to completely discount any relationships, as the sample size was too small.

8 Conclusions

8.1 Review

This project has looked at finding out whether or not people will react to avatars (virtual humans) in a virtual environment as they would with people in the real world. In order to answer this query a virtual bar environment was created within which were seven avatars (4 female and 3 male). These avatars blinked and breathed to give a continuous impression that they were active and not inert. Upon the pressing of various trigger keys by the author the avatars had been programmed to perform some basic animations relevant to the environment: drink a pint, shrug, look around, nod, walk to the bar and put out a hand to be shaken. When triggered, the avatars were also able to “speak” through pre-recorded sound bites.

An experiment was executed whereby the subject was placed inside the environment and asked to strike up conversation with the group of avatars standing near the bar (2 male and 2 female avatars).

From the initial findings of the experiments undertaken for this project the general result is that people react and interact with virtual humans as they would with real ones in the real world. This evidence reinforces the conclusions made from the studies done by Pertaub, Slater and Barker. The implications of these results are that virtual reality could be used as a means of treating sufferers of social phobia through exposure therapy. This would be of immense benefit to those suffering from the disorder and would aid them in leading normal lives.

8.2 Critique

The author wished she had thought more extensively about the purposes of the experiment when designing the avatar characters. The reason for this was that it was apparent as soon as the pilot was run that there were deficiencies in the “scripting” of the avatars as they made few animations that were not triggered by keyboard presses. The only automatic avatar animations were blinking and breathing. It would have added to the realism and interest of the scenario if the avatars had also done other small movements that people do such as shifting weight from one foot to the other.

The Virtual Wine Bar Experiment

The pilot subject (#1) commented “*Problem is didn’t know who’s talking to me and who asking me questions*” i.e. they were confused as it was not apparent who (out of the avatars) was talking. Subject #4 shared the same opinion as they remarked in the interview: “*it’s not clear who is speaking*” with respect to the underground train scenario. It would have been possible to give an indication of who was speaking by making the avatars point at themselves or turn towards the subject. Alternatively lip movement could have been included though this would have increased the complexity of the program and there was no time to incorporate this.

A difficulty in designing the experiment was to obtain the “right” amount of realism in the responses of the avatars. The more the avatars could respond “automatically” to the subjects the more difficult it would be to program but the resultant environment would be more realistic. However, there was also a limit to how much the responses could be directed by the person controlling the experiment. This was because an increase in avatar variables (such as more voice clips or more animations) would increase the amount of keys used to trigger animations. Subject #9 remarked that the avatar responses were “*often with bad timing*” which was due to the delay in deciding what response to generate and pressing the correct key. Increasing the number of possible responses would increase the delay.

One of the repeated comments given about the experiments was that people felt nervous because of the feeling of being watched (subjects #6 and #9), not by the avatars but by those running the experiment. For the underground train experiment this could have been eliminated, as there was no need for the investigator to watch the experiment (other than to take notes of reactions). However with the bar scenario it was imperative that the analyst was watching in order to know which animations and sound clips to trigger. However, not only was the feeling of being watched off-putting to the subject but so was the sound of the keys being tapped when triggering animations and sound clips (subject #9). One possible method of solving this problem would have been to have screened off the experiment and have a video feed of the subject fed back to the investigator or to have been able to view the subject through a one-way mirror. In this way the method of observation would have been less obvious also it would have helped to dampen the sound of the key presses.

The Virtual Wine Bar Experiment

A comment about the bar that was made was that it would have been more realistic had there been music playing in the background. This had been taken into consideration, however no method of incorporating background sound into the program was found that worked without stopping other sound files from being played at the same time such as the voice clips. One way of circumventing this problem would have been to play music from a CD player instead but having music playing in the background may well of created a difficulty in being able to hear what the subject was saying to the avatars.

8.3 Further Work

It has been found that when the avatars respond more realistically to the participants, the subjects in turn respond more naturally to the avatars. For instance with some of the questions asked of the avatars by the subjects were difficult to respond to given the limited number of responses that had been recorded. If this caused delay between the subject asking a question and the avatar responding, a break was likely to occur in any sense of presence that the subject had and make the subject feel that the avatars were not listening to them. This was clearly illustrated when the girl repeatedly asked how to get to Chinatown in the underground train experiment when a subject was in the seating part of the train and did not move. It was possible to see the subjects getting annoyed and it was remarked by subject #2 that it gave the scenario a lack of realism.

A few of the animations could be automated such as drinking and looking around which would leave the person controlling the experiment more time for triggering sound clips thus reducing the response time and also increasing the level of realism.

It would be useful to be able to measure the galvanic skin responses of the subjects in order to obtain another measure of their anxiety during the experiments. In this way it could be seen more clearly which particular “events” in the environment trigger the greatest increase in anxiety.

There is more work to be done in this field before virtual reality can be used in the treatment of social phobia. However, this experiment has successfully added to the knowledge already acquired and has given further evidence that people act and react to avatars as they would to “real” people.

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The Virtual Wine Bar Experiment

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Appendix A

Information Sheet for Participants

Thank you for volunteering to participate in this study. This is one in a long series of studies aimed at understanding people's responses to virtual environments.

Please read through this information and feel free to ask any questions. While the experimenters will be happy to answer any general questions you may have, they have been instructed not to discuss some aspects of the study until the end.

This study will take place inside a virtual reality room called a CAVE. You will be asked to wear a small tracking device attached to the head with a small adjustable strap. You will be asked to put on a pair of lightweight stereo glasses; these can be worn over eyeglasses if necessary. You will also be asked to take off your shoes to avoid marking the floor of the CAVE.

Procedures

- You will be asked to sign a Consent Form
- You will be fitted with sensors to measure your heart rate and galvanic skin response (palmar sweating)
- You will be asked to fill out 2 preliminary questionnaires
- You will then be led through to the CAVE
- You will have a brief practice period to get used to moving around the virtual environment in the CAVE
- Once you are comfortable, your task will be explained to you. You will be asked to move into another part of the virtual environment and observe it for 3-4 minutes
- Afterwards you will be asked to complete some further questionnaires about your experiences
- Finally there will be a discussion with the experimenters

The whole study is expected to take about 20 minutes.

Please note

- All your questionnaire responses will remain entirely confidential. No identifying information about participants will be published in any form
- Please do not discuss this study with anyone for ONE MONTH. This is because the study is continuing and you may happen to speak to someone who may be taking part.
- You are free to withdraw from the study **at any time** and **without giving reasons for withdrawing**.

A note about virtual reality equipment:

When people use virtual reality systems, some people sometimes experience some degree of nausea. If **at any time** you wish to stop taking part in the study due to this or any other reason, please say so and we will stop.

There has been some research which suggests that people using virtual reality displays might experience some disturbances in vision afterwards. No long term studies are known to us, but the studies which have been carried out do testing after about 30 minutes, and find the effect is still sometimes there.

The Virtual Wine Bar Experiment

There have been various reported side effects of using virtual reality equipment, such as "flashbacks."

With any type of video equipment there is a possibility that an epileptic episode may be generated. This, for example, has been reported for computer video games. For this reason we regret that we are unable to accept volunteers who are known to have suffered from epilepsy.

Appendix B

Virtual Reality Study Consent Form

Investigators: Laura James, Chien-Yu Lin, Mel Slater

Please read and answer the following questions carefully:

Have you read the information sheet about this study?	YES/NO
Have you had an opportunity to ask questions about the procedure?	YES/NO
Have you received satisfactory answers to all your questions?	YES/NO
Have you received enough information about this study?	YES/NO

Do you understand that you are free to withdraw from this study at any time and without giving a reason for withdrawing? YES/NO

Do you understand and accept the risks associated with the use of virtual reality equipment? YES/NO

Do you agree to take part in this study? YES/NO

We would like to videotape you when you are in the virtual environment, and would also like to audiotape the conversation at the end. These tapes will be used for data analysis purposes only and will be kept entirely confidential

Do you agree to be videotaped?	YES/NO
Do you agree to be audiotaped?	YES/NO

Please check:

I certify that I do not have epilepsy

I certify that I will not be driving a car, motorcycle, bicycle, or use other types of complex machinery that could be a danger to myself or others, within 3 hours after the termination of the study

Signed.....Date.....

Name in block letters

Appendix C

Questionnaire A

Thank you for agreeing to take part in this study. Please answer each of the following questions. Your responses will be treated completely **confidentially**, and results will only be referred to in statistical form or anonymously.

A1. Gender:

1. Male	1.
2. Female	2

A2.

<i>My status is as follows:</i>	Please tick against your answer
1. undergraduate student	1
2. Masters student	2
3. PhD student	3
4. Research Assistant/Research Fellow	4
5. Staff member - systems/technical staff	5
6. Faculty	6
7. Administrative staff	7
8. Other (please write in)...	8

A3. Have you experienced "virtual reality" before?

<i>I have experience virtual reality</i>	Please tick against your answer
1. never before	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. a great deal	7

A4. To what extent do you use a computer in your daily activities?

<i>I use a computer...</i>	Please tick against your answer
1. not at all	1
2.	2
3.	3
4.	4
5.	5
6.	6
7. very much so	7

The Virtual Wine Bar Experiment

A5.

This questionnaire is composed of statements regarding your feelings in social gatherings. Circle YES if you consider that the statement is true of your feelings most of the time. Circle FALSE if you consider that the statement is rarely true of you. Remember that this information is completely confidential

	Please circle
I feel relaxed even in unfamiliar social situations	YES NO
I try to avoid situations which force me to be very sociable	YES NO
It's easy for me to relax when I am with strangers	YES NO
I have no particular desire to avoid people	YES NO
I often find social settings upsetting	YES NO
I usually feel calm and comfortable in social situations	YES NO
I am usually at ease when talking to someone of the opposite sex	YES NO
I try to avoid talking to people unless I know them well	YES NO
If the chance comes to meet new people, I often take it	YES NO
I often feel nervous or tense in casual get-togethers in which both sexes are present	YES NO
I am usually nervous with people unless I know them well	YES NO
I usually feel relaxed when I am with a group of people	YES NO
I often want to get away from people	YES NO
I usually feel uncomfortable when I am in a group of people I don't know	YES NO
I usually feel relaxed when I meet someone for the first time	YES NO
Being introduced to people makes me tense and nervous	YES NO
Even though a room is full of strangers I may enter it anyway	YES NO
I would avoid walking up to and joining a large group of people	YES NO
When my superiors want to talk to me, I talk willingly	YES NO
I often feel on the edge when I talk to a group of people	YES NO
I tend to withdraw from people	YES NO
I don't mind talking to people at parties or social gatherings	YES NO
I am seldom at ease in a large group of people	YES NO
I often think up excuses in order to avoid social engagements	YES NO

The Virtual Wine Bar Experiment

I try to avoid formal social occasions	YES	NO
I usually go to whatever social engagements I have	YES	NO
I find it easy to relax with other people	YES	NO

Now return this completed questionnaire to the researchers.

Appendix D

Questionnaire B

Your responses will be treated completely **confidentially**, and results will only be referred to in statistical form or anonymously.

Please answer the following questions about your experience of meeting people in a virtual reality setting. Circle the number that best describes your experience.

1. How comfortable and relaxed did you feel with the people?

Not at all comfortable and relaxed 1 2 3 4 5 6 7 Very comfortable and relaxed

2. How pleased are you with the way you responded to the people?

Not at all pleased 1 2 3 4 5 6 7 Very pleased

3. How much did you have a sense that there were people there in the situation with you?

Not at all 1 2 3 4 5 6 7 Very much

4. How much did you have a sense of talking to other people?

Not at all 1 2 3 4 5 6 7 Very much

5. Was it more like just talking to a computer or communicating with people?

Like a computer 1 2 3 4 5 6 7 An audience

6. How aware were you of the the people?

Not at all aware 1 2 3 4 5 6 7 Very aware

7. What sort of impression do you think you made on them?

Very negative impression 1 2 3 4 5 6 7 Very positive impression

8. How friendly were they?

Very unfriendly 1 2 3 4 5 6 7 Very friendly

The Virtual Wine Bar Experiment

9. How interested were they in what you had to say?

Not at all 1 2 3 4 5 6 7 Very interested
interested

10. How much would you like to meet with them again?

Not at all 1 2 3 4 5 6 7 Very much

11. How do you rate your own social performance in this situation. Assign to yourself a score out of 100.

0 = completely dissatisfied with your performance.

100 = completely satisfied.

I would rate my social performance as:

Score / 100

12. People sometimes experience physical discomfort meeting new people for the first time. Did you experience any of the following? Please circle either yes or no.

	Please circle	
Sweating (clammy palms, perspiration)	YES	NO
Discomfort in the stomach (butterflies)	YES	NO
Heart Palpitations	YES	NO
Tremors (shakiness)	YES	NO
Nerves / feeling of being scared	YES	NO
Tightness in chest	YES	NO
Tenseness	YES	NO
Loss of balance	YES	NO
Nausea	YES	NO

The Virtual Wine Bar Experiment

13. Which of the following apply to the presentation you just gave? Please circle either yes or no:

This questionnaire is composed of statements regarding your feelings in this particular social setting that you have just experienced in the virtual reality. Circle YES if you consider that the statement was true for feelings in that situation. Circle FALSE if you consider that the statement was not true for you. Remember that this information is completely *confidential*

	Please circle
I felt relaxed	YES NO
I wanted to avoid the situation	YES NO
It was not easy for me to relax with those strangers	YES NO
I had no particular desire to avoid them	YES NO
I found it upsetting	YES NO
I felt calm and comfortable	YES NO
I was at ease when talking to someone of the opposite sex	YES NO
I wanted to try to avoid talking to them because I didn't know them	YES NO
I took the chance to meet new people	YES NO
I felt nervous or tense	YES NO
I was nervous with people because I didn't know them	YES NO
I felt relaxed even though with a group of people	YES NO
I often wanted to get away from those people	YES NO
I felt uncomfortable because I didn't know them	YES NO
I felt relaxed even though meeting these people for the first time	YES NO
Having to introduce myself made me tense and nervous	YES NO
Even though it was full of strangers I felt comfortable to go in anyway	YES NO
I wanted to avoid walking up to and joining a this group of people	YES NO
I talked willingly with them	YES NO
I often felt on the edge when I thought about talking to them	YES NO
I tended to withdraw from the people	YES NO
I didn't mind talking to them	YES NO
I was seldom at ease with them	YES NO

The Virtual Wine Bar Experiment

I was trying to think up excuses to avoid being with them	YES	NO
I tried to avoid this situation	YES	NO
I had no problem to go over to them	YES	NO
I felt it easy to relax with the other people	YES	NO

14. What were the best things about your encounter with the other people?

15. What were the worst things?

16. Please add any other comments about your experience.

Thank you for completing our questionnaire. We hope you enjoyed your opportunity to meet virtual people. Please now return this questionnaire to the research staff.

PLEASE DO NOT DISCUSS THIS WITH ANYONE ELSE FOR THE NEXT TWO MONTHS SINCE THE RESEARCH IS CONTINUING.

Appendix E

Social Phobia in a Virtual London Underground Train and in a Wine Bar: Analysis of Results of a Pilot Experiment¹

Mel Slater, September, 2002

1. Introduction

Ten subjects selected by advertisement from amongst graduate students in the Computer Science Department at UCL were exposed to scenes presented in virtual reality. The purpose was to examine the extent to which social anxiety tendencies could be triggered within the virtual reality environment. This was considered a pilot experiment and therefore the subjects were not paid for their participation.

The scenes that they experienced were either a relatively socially neutral journey in a London Underground train and a more socially hostile visit to a wine bar. In each experience there were a number of animated avatars. For the train journey there was no specific instruction to the subject, and the only response of the avatars was that one of them occasionally looked at the subject, and if the subject attempted to sit down, one of the avatars would ask them a question ('How to get to Chinatown') in order to prevent the action of sitting from taking place. In the wine bar, the subjects were asked to interact with the avatars, who responded often in a socially negative manner – such as saying 'Whatever' in response to a question, or shrugging or walking away.

Half of the subjects experienced the train ride first followed by the wine bar experience, and the other half experienced the opposite order. Each experience was for about 2 minutes, and was carried out in a 4-walled immersive stereo projection Cave-like system, the Trimension ReaCTor.

2. The Variables

A questionnaire was administered before the experience, which gathered basic information such as status (there were 14 MSc students, 4 PhD students, and 2 Research Assistants), the extent of the experience of virtual reality before, and gender. In fact there was a uniform gender distribution, such that each subgroup in the experimental design had 50% men and women.

¹ This is based on an experiment carried out by Laura James and Chien-Yu Lin for their MSc VIVE project, and is provided for the purposes of their reports.

The Virtual Wine Bar Experiment

The most important information gathered from this initial questionnaire was the standard Socially Affective Disorder (SAD) questionnaire. This provides 27 Yes/No questions assessing generalised social phobia in everyday life. The higher the count the greater the social phobia.

After each experience a second questionnaire was administered. The most important data collected was again a SAD questionnaire, but this time with the questions adjusted so that they clearly referred to the previous experience, rather than to the typical responses in everyday life. The point was to try to assess the degree of social anxiety generated by that particular experience. The result was therefore also a count of negative responses out of a maximum of 27.

A second important response variable elicited from this questionnaire was concerned with subjective physiological responses. There were 9 physiological responses: Sweating (clammy palms, perspiration), Discomfort in the stomach (butterflies), Heart Palpitations, Tremors (shakiness), Nerves / feeling of being scared, Tightness in chest, Tenseness, Loss of balance and Nausea. The questionnaire required a Yes/No answer to each of these possible conditions in response to the last experience (train or wine bar). This is important since current social phobia theory suggests that social phobics tend to focus inwardly and become overly aware of their physiological state – so that, for example, a slight increase in heart rate is experienced as a massive increase.

There were a number of informal questions on the extent of co-presence with the avatars (the sense of being with other people) and also on aspects of the subjects' overall social comfort in the scenario just experienced.

The fundamental response variable of interest was the SAD count after the experience, but taking into account the generalised SAD count obtained from the pre-experience questionnaire. We would expect, taking into account order of presentation, that if the avatars are socially effective, then:

The more neutral setting would evoke less anxiety than the more overly hostile and clearly social setting (the wine bar)

There should be a positive relationship between pre-SAD, post-SAD and subjective physiological response.

Order of experience may change the anxiety associated with an experience (familiarity may result in a diminished response).

3. Analysis

Following previous studies the response variables (post-SAD and subjective physiological response) were treated as binomial random variables (counts of an anxiety response out of a maximum possible number), and logistic regression was used to find the relationship between the response and independent or explanatory variables.

Consistency

The pre- and post-SAD responses are positively and significantly correlated (R-squared = 0.21, $n = 20$).

The Virtual Wine Bar Experiment

Post-SAD is significantly and positively correlated with subjective physiological response (R-squared = 0.76).

Post-SAD is also significantly negatively correlated with the subjects' overall self-assessment of their social performance (their own assigned score out of 100, where 100 would mean their best possible performance) (R-Squared = 0.28).

Post-SAD

We fit the core regression model consisting of scene, order, and pre-SAD, with results shown in Table 1.

The chi-squared values are on 1 d.f., and show the reduction in model fit that would be caused by deletion of that corresponding variable. The chi-square tabulated value at 1 d.f. is 3.841 at 5% significance and therefore none of these variables can be deleted without loss of model fit. As expected, post-SAD is significantly positively correlated with pre-SAD, increases for the wine bar scene compared to the train scene, and decreases with order.

Table 1: Logistic Regression for Post-SAD

Variable	Coefficient	Standard Error	Chi-Squared (1 d.f.)
Scene (wine bar)	0.59	0.20	9.2
Order	-0.63	0.20	10.3
Pre-SAD	0.093	0.018	28.9

The overall model fit has a chi-squared value of 90.7 on 16 d.f.

Subjective Physiological Response

A regression model with subjective physiological response as the dependent variable yields the same result as for post-SAD, as shown in Table 2.

Table 2: Logistic Regression for Subjective Physiological Response

Variable	Coefficient	Standard Error	Chi-Squared (1 d.f.)
Scene (wine bar)	1.1	0.51	5.1
Order	-1.3	0.53	6.9
Pre-SAD	0.11	0.045	6.0

No variable can be deleted from the regression without a significant loss of fit (at the 5% significance level).

The overall model fit has a chi-squared value of 23.5 on 16 d.f. (a very good overall fit).

Experiencing Virtual Reality Before

For both analyses, if the extent of prior virtual reality experience (self-assessed on a 1 to 7 scale) is taken into the model, then it is significant and is associated with a reduction in anxiety. In each case there is also a positive interaction effect with order, so that the greatest reduction in anxiety occurs for those who have experienced virtual reality before and in relation to their second exposure for this experiment.

4. Conclusions

This note has provided a regression analysis of the fundamental variables in the experimental design. The results suggest that social anxiety can be generated within a virtual social setting – in particular a socially neutral setting will tend to provoke less anxiety than a more charged setting. This is in spite of the lack of realism of the avatars, and of course, the very strong dissimilarity between real social settings, with all their varieties of complex behaviours, and these very simple computer generated ones. These results repeat the earlier findings in relation to fear of public speaking (negative audiences invoke significantly greater anxiety than positive virtual audiences) and if these results are established over time with further experimentation, there is good prospect for the exploitation of virtual reality in social phobia therapy. However, the evidence also suggests that repeated exposures reduce the effectiveness of the simulation in the generation of anxiety. Of course, this in itself may be useful, since the fundamental idea of ‘exposure therapy’ is that increasing levels of exposure under suitably controlled conditions does reduce levels of anxiety.

Appendix F

Transcripts of Experiments and Interviews for subjects 1-5

Transcripts: Tuesday, 20th August 2002

S = subject L = Laura C = Chien *...* = recorded voices in program

Subject #1: Tube

* Excuse me how to get to china town? *

S: can't hear!

S: can't hear! Could you repeat it please?

* Excuse me how to get to china town? *

S: I'm not sure

*** This is Finsbury park please change here for Piccadilly Line and National rail services. The next station is Manor House ***

Subject #1: Bar

S: It's not working

L: I'll just shut the window and start again. This should work.

S: Hello!, hello! Anyone hear me? What's your name?

* Nice to meet you *

* Fascinating *

S: Can't hear can you say again

* I'm Zoë *

S: How are you today

* Yeah, yeah. Yeah, yeah *

* Fascinating*

S: Hello

You really do lead a fascinating life

* I'm May. I'm May*

S: What you doing there? Hello?

* Nice to meet you*

S: Nice to meet you too. Can you buy me a drink?

* Whatever*

S: Thanks

* Mm hmm. Mm hmm*

* Riveting. I'm off to the bar*

S: Hello what's the time now

You really do lead a fascinating life

S: Hello? I can't hear you properly

* Hi. *

S: Who's talking to me?

* Nice to meet you. I'm May.*

* slurp*

S: Why you standing here?

* Yeah, yeah*

* Oh is that the time? I really must be going! *

S: Ok

L: Time to stop now.

L: Are you okay?

S: A bit tired. It's heavy

Subject #1: Interview:

The Virtual Wine Bar Experiment

L: How's that feel? Was that ok?
S: Um... the second one's better
L: Any particular reasons?
S: Don't actually know what's going on in first one!
L: Right. Okay.
L: Um. Did you notice in the first one there was a guy following you with his head?
S: Not quite notice it!
L: Right! Did you feel they were looking at you? The avatars?
S: Yeh. bit
L: Was that in the first one? The second one? Both?
S: Both
L: Ok
L: How does that feel like?
S: Bit weird actually
S: Problem is didn't know who's talking to me and who asking me questions
L: right ok
L: So did you feel like you were in the environments? Or not really?
S: It was ok I think
L: Do you have any more comments on either of the scenarios?
S: Um. Their mouth actually talking like moving. I can't really see them! *laugh
L: Um anything else?
S: Um. Can't quite hear properly actually
C: What is your first reaction when you hear someone asking you question in first one
S: Strange! Didn't expect someone asking me question!
L: How did you feel when they were being sarcastic in the second one like saying *really interesting*. Did you feel like it was a personal attack on you or not?
S: No..
L: That's it. Thanks!

Subject #2: Bar

L: When the program is run you'll be in a bar. There'll be a group of people in front of you. If you could just go over to them and start a conversation. When your time's up I'll let you know and switch off the program. If you feel uncomfortable at any time let me know.
S: So I have to start a conversation with the avatars?
L: Yes!
S: Oh my God! Hehe!
L: So do you understand what you need to do?
S: So will they talk as well?
L: You'll find out!
S: Ok it's just something talking on my own!
L: So if you feel uncomfortable let me know and I'll just stop it! It'll take a minute to load up then it'll be run. Any questions?
S: Will I be able to understand them?

S: Hello!
* I'm Zoë *
* I'm may *
S: Hi may
* Fascinating *
S: Nice to meet you. Do you come here very often?
* Mm hmm *
S: sorry? Oh look at him drinking again
* laugh *
* laugh *
* Gee you really do lead a fascinating life *
S: so what do you do?
* Errrgggghhh my name's Tim I'm really not feeling very well*
* Errrgggghhh my name's Tim I'm really not feeling very well*

The Virtual Wine Bar Experiment

* Riveting. I'm off to the bar!
* laugh *
* Yeah, yeah *
* Oh, is that the time, I really must be going! *
L: okay that's the end thanks.
S: Yep. I'm sorry but I don't know what's going on!
L: Are you ok?
S: Is it ok? Yes.
L: Are you alright?
S: Yes yes yes!

Subject #2: Tube

C: The second experiment is about after the bar you need to go home now so you travel by tube. So, after bar you go home. Enjoy the tube!
S: Do I have to talk to them?
C: Er.
S: Cause in the tube nobody talks in London!
C: You have to react if something happens!
S: Okay, okay!

* Excuse me how to go to Chinatown? *
* Excuse me how to go to Chinatown? *
* Excuse me how to go to Chinatown? *
* Excuse me how to go to Chinatown? *
* Excuse me how to go to Chinatown? *
S: I'm not sure... the first line... so
* This is Finsbury Park. Change here for the Piccadilly line and national rail services. Please mind the closing doors. The next station will be manor house. *

Subject #2: Interview

L: Ok, so what did you think?
S: Ok the first experiment in the bar? I didn't really have the feeling of a very real situation
L: mm hmm?
S: cause first of all when you go to a bar you don't go directly to the people. So in the moment you ask us to go directly is isn't very real... and... and also you don't have a proper conversation. You have the feeling you're talking on your own a little bit so it's not that you feel uncomfortable because of the situation or you're in a bar or with people its because of the behaviour it's not the one you'd expect and also maybe if there were some music it would give you the feeling you were in a real bar...
L: Umm hmm
L: It's because we couldn't actually do that because if you run it in the background it stops the people speaking!
S: Ok! Maybe just put a radio next to it!
L mm hmm!
S: No it's just that it feels a bit strange. And then the tube on the one hand it feels a bit more realistic because no one talks to you usually unless you're with your friends etc. The problem in the tube was the girl was asking me how to go er, I don't know where. She asked that like 6 times and *laugh. Gives you the feeling is she really interested or is she stuck with the question? Only that but the environment feels more real than the bar maybe
L: right
C: Do you feel that there's someone is staring at you on the tube?
S: What do you mean?
C: Keep on looking at you whenever you go past
S: Ah the people was... not really no they were like just on there own. The one was the girl asking for the stop
C: Ok no. Any other comments?

The Virtual Wine Bar Experiment

S: I think that's it. It's just that the sound it would really help if it was like more realistic. Like if you have people talking and it matches better the reality it would really help but if it doesn't really match with the reality it may give you the feeling of not being in a real situation. Don't you think so?

L: Umm hmm ok.

S: Ok that's it

C: Thank you!!

Subject #3: Bar

L: It'll just take a minute to load up

S: Where do I have to look? to the wall?

L: Yep. Ok?

S: Hi!

S: Hi, how are you? Are you having a drink?

S: Ok shall I ask for one?

S: Hi! Could I have a drink please?

S: Vodka and juice. Thank you. Ah?

S: Who do I have to talk to the people in the bar or whatever?

S: Hi are you student? Are you at UCL?

S: laughs

S: Could I try?

S: This is nice! Okay my name is Marta, nice to meet you! Laughs

S: Hi nice to meet you!

L: okay I'm going to stop now. We seem to be having a problem with the sound
(..... conversation about what's happened with the sound)

S: So shall I put everything again

L: Yeah thanks

S: Yeah? These?

L: That's fine thanks, sorry about this!

S: No don't worry. really.

S: Shall I speak to them like before?

L: Yeah

S: Can I say the same things?

L: Yes you can say what you want to!

S: Hi could I have a drink? Hello

* really*

S: Yeah could I have a vodka and...

* Oh, is that the time I really must be going *

S: Hi, my name is Marta. Nice to meet you. What's your name?

* Fascinating *

* I'm May *

S: hi, nice to meet you!

S: Ok and what's your name?

* Fascinating *

S: nice to meet you!

* I'm Zoë *

S: Why? Why? Nice to meet you, ok.

S: Hi

* Errrgggghhh my name's Tim I'm really not feeling very well *

S: Ok nice to meet you Tim! Are you working or studying?

* Oh is that the time? I must be going *

S: Oh really? Ok.

* Gee, You really do lead a fascinating life *

S: oh thank you! I'm studying at UCL I am a Phd student. What are you doing?

* Fascinating! *

The Virtual Wine Bar Experiment

S: Thank you
* Riveting, I'm off to the bar! *
S: Can I go with you? Hehe... hehe
* I'm Zoë *
S: why are you sorry?
* I'm Zoë *
S: Do you want something to drink?
* I'm May *
S: Hi, nice to meet you!
* Whatever *
S: Very nice knowing you!! Hum!

L: Ok that's the end now
S: Whatever! I don't like her!
L: Thank you!

Subject #3: Tube

C: we are going to run the second experiment. When the scene is load up we will be on tube
S: On tube?
C: Because after bar you need to go home on tube. You can move around the tube and just enjoy the ride to see what's change inside
S: So do I have to speak or something? Or just be there
C: Um. No
S: Ok. Just be there! Ok

* Excuse me how to go to Chinatown? *
* Excuse me how to go to Chinatown? *
S: You have to take the... you have to leave the tube in Leicester Square then ask around there
* Excuse me how to go to Chinatown? *
* This is Finsbury Park. Change here for the Piccadilly line and national rail services. Please mind the closing doors. The next station will be manor house. *

Subject #3: Interview
(Not recorded. Just notes taken)

Bar

Felt ignored because the avatars did not always reply
Subj. not nervous of meeting new people but didn't like being ignored
Didn't like Zoë because she was rude and when subject asked her if she wanted a drink Zoë (avatar) just replied "whatever"
Subj. tried to be nice to the avatars but they were not nice back
Liked the fact that Zoë walked off and she could walk with her
Subj. tried to 'be' in the environment even though knew it wasn't real
Couldn't tell if avatars understood or not

Tube

Felt more contained in the tube
Person in the tube that asked for directions was rude as when replied the avatar didn't say thanks
Subj. felt maybe should have said sorry when walked past person on the tube
Subj. felt like avatars were watching her on tube

Subject #4: Tube
Not recorded
Subject #4: Bar
Not recorded

Subject #4: Interview
L: What did you think of that? Think of the scenarios?
S: Um... I don't know!

The Virtual Wine Bar Experiment

C: Just, any suggestion!
S: Any suggestion?
L: Did you feel like you were 'in' the environments?
C: Yeah
L: Or did you feel you were in a computer game?
S: More like playing computer games really isn't it?! *laugh* I know they're not real *laugh*
L: Did you find yourself responding to them as you would to normal people?
S: Yes. Probably. Um hmm. Yes.
L: And how did you feel when on the tube. They were watching you?
S: They were watching me? How did I feel?
L: Yeah did you feel like they were watching you?
S: One of them were
L: Um hmm
S: Because I try to find out who's speaking to me *laugh*
C: Why is that so?
S: Because it's not clear who is speaking. There is no mouth movement really. Or I couldn't spot any!
Maybe. Maybe it was too dark I'm not sure
L: Umm hmm. Did you think that they were friendly, the people in either situation
S: Ooh in the bar they were quite friendly I feel. Some of them introduced their names in the tube
laughs it was quite annoying when the girl kept repeating the questions!! *laughs*
L: Umm. Anything else to add?
S: No. Not really no!
L: Ok that will do!

Subject #5: Tube

* Excuse me how to go to Chinatown? *
S: Eh?! Sorry?
* Excuse me how to go to Chinatown? *
S: I don't really understand what I have to do... I have to answer the girl?
C: You can answer or whatever you want!
S: Ok!
* This is Finsbury Park. Change here for the Piccadilly line and national rail services. Please mind the closing doors. The next station will be Manor House. *

C: that's the end of first experiment...

Subject #5: Bar

* I'm Zoë *
* I'm Zoë *
S: Hello I'm Maryline
* I'm May *
S: Excuse me, I am searching for a friend. Andy. Do you know where he could be?
* Nice to meet you *
S: Nice to meet you too!
* Yeah, yeah *
S: * laughs *
* Uh huh! *
S: what are you drinking?
* Really *
S: * laughs * can I have a beer please
* Really? *
S: Thank you
* Yeah, yeah *
* Fascinating *
S: fascinating!!
* Laugh *
* I'm Zoë *

The Virtual Wine Bar Experiment

* Riveting. I'm off to the bar! *
(pause)
* Nice to meet you *
* Yeah, yeah *
* Oh is that the time? I really must be going! *
L: Ok that's the end.
S: I'm sorry I am not very used with English though
L: No that's ok
S: So I don't know what to do
L: Thank you. Do you feel ok?
S: Yeah

Subject #5: Interview

L: So what did you think of the two experiments, scenarios?
S: It was funny. The drawings were very beautiful and it was fun but I really don't really know what to do in there and I can't really speak with the people cause I know it's not real and they don't really answer.
* Disturbance. Break in interview *
L: You felt they weren't real because they didn't answer you properly?
S: Can you just repeat
L: You felt they weren't real because they didn't answer you properly?
S: Yeah they, they speak they say "yeah, yeah". It was not really question. It was not real question so I don't feel er... in a real discussion
L: Ok. Did you feel they were friendly or unfriendly?
S: Um... no they was friendly. They were really and er...
L: Ok. And when you were on the tube did you feel like they were watching you?
S: Um yes! I feel I was alone standing and all the people sit and look at me because I can't sit because there was no room for me! *Laughs*
L: Ok. And did you feel like you responded to um... them as if they were real people like if they did say "hello" or I didn't know if you noticed but one of them put out their hand to shake your hand...
S: Um I think I would have done it if he just... I would try to shake their hand
L: Um. Any questions?
C: Umm...
L: Do you have any further comments?
C: Yeah, other comments?
S: No, it's ok!
L: That's ok. That's great. Thank you for your time!
C: Yes, thank you! Goodbye!

Appendix G

Answers to the open-ended questions at the end of Questionnaire B

14. *What were the best things about your encounter with the other people?*

15. *What were the worst things?*

16. *Please add any other comments about your experience.*

Subject #1: Tube

- 14. facial expressions
- 15. communication
- 16. don't know who is asking me question and didn't expect it at all

Subject #1: Bar

- 14. facial expressions
 - 15. communication
 - 16. can't hear quite properly. It seems they didn't give me a right response. Don't know who is talking to me
-

Subject #2: Bar

- 14. The opportunity of meeting new people
- 15. The worst thing is I didn't really have the feeling of having a normal conversation cause they weren't answering my questions nor trying to make me question. So I didn't feel nervous because of being with new people but I had the feeling they weren't interested in talking to with me and neither was i.
- 16. It would be more realistic if there was some music

Subject #2: Tube

- 14. there was nothing I could consider the best cause there was nothing really special
 - 15. the fact that the woman asked me 5 times the same thing it made me feel a lack of realism
 - 16. –
-

Subject #3: Bar

- 14. to see that I had a bit of feedback sometimes
- 15. that most of the time I felt ignored
- 16. it was great to be inside of the cave. I enjoyed it, but I felt a bit uncomfortable at some points because they didn't reply me as much as I was expecting.

Subject #3: Tube

- 14. I tried helping them
 - 15. I could not seat!
 - 16. This time when I left I felt a little bit more dizzy. Maybe because the space was tighter.
-

Subject #4: Tube

- 14. when he is facing me
- 15. when she keeps repeating the questions
- 16. –

Subject #4: Bar

- 14. when they introduce their names
-

The Virtual Wine Bar Experiment

15. they don't respond to what I said
16. -
-

Subject #5: Tube

14. I don't know or perhaps I just don't really understand the question
15. I don't know!
16. I should have asked first what was the aim of the experiment because I didn't know what to do in the cave

Subject #5: Bar

14. don't know
15. don't know
16. 16 no comments
-

Subject #6: Bar

14. I manage to say something that didn't sound completely stupid.
15. They didn't want to know me.
16. I think the thing that really made me tense above all else was the fact that I was being watched doing the task. It was like I was doing a test.

Subject #6: Tube

14. I was able to provide helpful information
15. None
16. I didn't feel I needed to say anything to anyone.
-

Subject #7: Tube

14. Their gesture.
15. -
16. the woman standing opposite the doors was quite off putting due to proximity + stare.

Subject #7: Bar

14. Give you an answer
15. their response.
16. Was quite strange, in a way think felt more uncomfortable because they weren't real.
-

Subject #8: Bar

14. I knew they weren't real so I didn't care that we didn't cut it off. It was interesting.
15. Felt there would have seen more delay or to who was speaking. I felt disoriented in the cave. Don't feel real. Their comment were unrealistic.
16. fun project

Subject #8: Tube

14. -
15. -
16. wasn't made an encounter. Little interaction and didn't feel like I connected with the woman asking for Chinatown.
-

Subject #9: Tube

14. I had a sense of it not being real so I was fairly relaxed apart from the feeling of people looking (the real people outside the cave).
15. She kept repeating the same thing over and over! -- weird. Also, too no notice of my replies.
16. It's more about the other people looking at you than about the simulation, in my mind.
-

The Virtual Wine Bar Experiment

Subject #9: Bar

- 14. -
 - 15. Simple answers, often with bad timing.
 - 16. I could hear keyboard clicking in the background, like commands were being issued to the avatar. This was distracting and detracted from the feeling of presence.
-

Subject #10: Bar

- 14. New experience. New faces. Exciting.
- 15. "whatever". Not very responsive to what I said..
- 16. -

Subject #10: Tube

- 14. -
- 15. she didn't listen. She was repeating the same question. She wasn't friendly.
- 16. -

Appendix H: Results from Questionnaires A and B

The Virtual Wine Bar Experiment

Appendix I: CubesApp.cpp

Appendix J: CubesApp.h

Appendix K: lauraConfig.config

```
Keyboard
  Name "Avatar Control"
  width { "200" }
  height { "75" }
  origin { "200" "200" }
  msens { "1.0" }
  display_number { "0" }
  lock_key { "KEY_NONE" }
  start_locked { "False" }
  sleep_time { "75" }
end
KeyboardProxy
  Name "Main Keyboard"
  device { "Avatar Control" }
end
proxyAlias
  Name "VJKeyboardLKJ"
  aliasName { "VJKeyboardLKJ" }
  proxyPtr { "Main Keyboard" }
end
End
```

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