# Anxiety Activating Virtual Environments for Investigating Social Phobias

by

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# Abstract

Social phobia has become one of the commonest manifestations of fear in any society. This fear is often accompanied by major depression or social disabilities. With the awareness that fear can be aggravated in social situations, virtual reality researchers and psychologists have investigated the feasibility of a virtual reality system as a psychotherapeutic intervention to combat social phobia. Virtual reality technology has rapidly improved over the past few years, making for better interactions. Nevertheless, the field of virtual reality exposure therapy for social phobia is still in its infancy and various issues have yet to be resolved or event uncovered.

The key concept of virtual reality exposure therapy in the treatment of social phobia is based on its characteristic of perceptual illusion - the sense of presence - as an anxiety-activating system, instead of conventional imaginal or in-vivo exposure techniques. Therefore, in order to provoke a significant level of anxiety in virtual environments, it is very important to understand the impact of perceptual presence factors in virtual reality exposure therapy. Hence, this research mainly aims to investigate all the aspects of the correlation between anxiety and the components of the virtual environment in a computer-generated social simulation. By understanding this, this thesis aims to provide a framework for the construction of effective virtual reality exposure therapy for social phobia care which enables anxiety stimuli to be controlled in a gradual manner as a conventional clinical approach.

This thesis presents a series of experimental studies that have been conducted with a common theme: the function of 3D inhabitants and visual apparatus in anxiety-activating virtual social simulation, a job-interview. However, each study is conducted using different research objectives. The experimental results are presented in this thesis, with psycho-physiological approach, revealing a variation of the distribution of participants' anxiety states across various VR conditions. The overall conclusion of this research is that an appropriate realism of VR stimuli is essential in sustaining the state of anxiety over the course of VR exposure. The high fidelity of virtual environment generally provoke a greater degree of anxiety, but this research also shows that aspects of VR fidelity is more related to the mental representation of individuals to the context of the stressful situation rather than any technology that is being used.

# List of Publications

## Publication

- Joung H. Kwon, John Powell, Silvester Czanner, Gabriella Czanner, Alan Chalmers (under review), Virtual Reality Exposure for Job Interview Phobia, Journal of CyberPsychology and Behavior

## Conference Papers

- Czanner Silvester, Petrasove Alena, Kwon Joung Huem, Chalmers Alan (2009) Mathematical Modelling For Development of Egocentric Virtual Environments, Aplimat 2009, Journal of Applied Mathematics
- Joung. H. Kwon, Alan Chalmers, Silvester Czanner, Gabriela Czanner, John Powell (2009) A Study of Visual Perceptions: Social Anxiety and Virtual Realism, Proceedings SCCG 2009, Journal of ACM SIGGRAPH: ISSN 1335-5694

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- Joung H. Kwon (2009), Virtual Reality Exposure Therapy: Social Anxiety and Virtual Realism, British Computer Society - Branch of Coventry

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# List of Abbreviations

- ANOVA Analysis Of Variance
- ATPS Attitude Towards Public Speaking questionnaire
- BDI Beck Depression Inventory
- BFNE Brief Fear of Negative Evaluation
- CAVE Computer Automatic Virtual Environment
- CBGT Cognitive Behaviour Group Therapy
- CBT Cognitive Behaviour Therapy
- CGI Clinical Global Impression
- CT Cognitive Therapy
- DSM Diagnostic and Statistical Manual
- DSM-III The Third Edition of the Diagnostic and Statistical Manual of Mental Disorders
- ECG Electrocardiographic
- EMG Electromyographic
- FNE Fear of Negative Evaluation questionnaires
- FOPS Fear of Public Speaking
- FOV Field of View
- GPU Graphic Processing Units

- HAD Hospital Anxiety Depression scale
- HMD Head-Mounted Display
- HRTF Head Related Transfer Function
- ICD-10 International Statistical Classification of Diseases
- IPD Inter-Papillary Distance
- IPT Interpersonal Therapy
- IQ Immersion Questionnaire
- LSAS Liebowitz Social Anxiety Scale
- LZ Look-Zone
- MASI Measure of Anxiety in Selection Interviews
- MLM Mixed Linear Models
- PERCLOS Percentage of Eye Closure
- PRCA Personal Report of Communication Apprehension
- PRCS Personal Report of Confidence as a Speaker
- PQ Presence Questionnaire
- RAS Rathus Assertiveness Schedule
- RET Rational-Emotive Therapy
- SAD Social Avoidance and Distress Scale
- SCR Skin Conductance Response
- SISST Social Interaction Self-Statement Test
- SoP Sense of Presence
- SP Social Phobia
- SR Stimulus-Reactions

- SSI Shuttering Severity Instrument
- SSPS Self-Statements during Public Speaking
- SSRIs Selective Serotonin Reuptake Inhibitors
- STAI State-Trait Anxiety Inventory
- SUD Subjective Units of Disturbance
- VEs Virtual Environments
- VR Virtual Reality
- VRET Virtual Reality Exposure Therapy
- 3D Three-Dimensional

# List of Tables

# List of Figures

# Contents

CHAPTER 1

# Introduction

Virtual Reality (VR) is an innovative computer interaction technology in which people are no longer simple observers of images on a computer screen, but can feel the illusion of being a participant in a computer-generated three-dimensional (3D) virtual world (Gutierrez-Maldonado *et al.*, 2008). In many VR applications, this concept has been used to simulate the real world and to assure the user full control of all the parameters, such as the sense of time and space and a degree of interactivity. This characteristic has recently attracted much attention in the field of clinical psychology.

North and his colleagues introduced the world's first virtual reality system for therapeutic purposes and successfully demonstrated its potential benefits to agoraphobia (North *et al.*, 1995). Thereafter, an increasing number of case studies have shown the success of virtual reality for treating a wide range of psychological conditions, including the fear of public speaking (Anderson *et al.*, 2005), heights (Choi *et al.*, 2001), flying (North *et al.*, 1997), spiders (Garcia-Palacios *et al.*, 2002), open spaces (Botella *et al.*, 1998), and so on.

In the meantime, the fear of social interactions (also called social phobia) has become one of the commonest manifestations of anxiety in society (Kessler *et al.*, 1994 and Stein *et al.*, 1996). Individuals who suffer from social phobia have feelings of self-consciousness, judgment, evaluation, and inferiority that are involuntarily caused by their interactions with other people (APA, 1994). This can have a devastating effect on their social lives, for example, choice of career, business trip, job interviews and other social interactions in educational or workplace environments (Deborah *et al.*, 1999). Unlike other specific phobias (e.g. spiders, dogs, or flying), social phobia is not limited to a certain situation, and is often accompanied by major depression or substance abuse (e.g. alcohol or drugs). It thus requires more sophisticated and assorted clinical techniques to treat social phobia (Stein *et al.*, 1990; Merikangas & Angst, 1995; Lewinsohn *et al.*, 1997).

With the awareness that fear can be aggravated in social situations, North and his research team developed a VR therapeutic tool to help combat the fear of public speaking (FOPS) in 1998 (North *et al.*, 1998). They designed a virtual auditorium, with audiences that were programmed to respond to a presenter. This study carried out and demonstrated the feasibility of virtual reality for the fear of social interactions. Since then, several academic research groups around the world (including North's research group) have worked on this topic with different VR technology and various case studies. For instance, Lee's research team (*Biomedical engineering group, University of Hanyang, Korea*) applied a virtual image-based rendering system to FOPS (Lee *et al.*, 2002), Pertaub's research group (*Computer Science, University College London, United Kingdom*) developed the Distributed Interactive Virtual Environment system based on virtual reality simulation for the FOPS (Pertaub *et al.*, 2002), EPFL-VRlab (*Ecole Polytechnique Federale de Lausanne, Switzerland*) developed a cognitive behaviour virtual reality therapy for social phobia (Grillon *et al.*, 2006), GREYC (*Groupe de Recherche en Informatique, France*) compared a VR therapy to clinical treatments (Klinger *et al.*, 2005), and other research teams realised the effectiveness of virtual reality in the treatment of social phobia (Anderson *et al.*, 2005 and Cornwell *et al.*, 2006).

While the studies that have been carried out up to now have found that VR is an effective technique for the treatment of certain types of social phobia, there is still much uncertainty about the reasons for this. It seems that more research is needed to test a broad range of hypotheses, from the function of perceptual apparatus to the function of inhabitants in virtual social situations. In addition, more experimental studies regarding effectiveness are required to explore this topic further and to draw more specific conclusions.

## 1.1 Research Aims

This research focuses on examining all the aspects of the correlation between anxiety and the components of the virtual environment in a computer-generated social simulation that has been designed for the treatment of one type of social phobia. The ultimate goal of this research was to understand the impact of perceptual presence factors in social-anxiety-provoking virtual environments. By understanding this, this thesis can suggest a framework for the construction of effective virtual reality exposure therapy for social phobia care which enables anxiety stimuli to be controlled in a gradual manner.

The detailed research aims are:

- ✓ *To review the evidence of different treatments for social phobia.*
- ✓ *To identify design issues in the development of virtual reality exposure therapy for social phobia.*
- ✓ *To develop a model of anxiety-provoking virtual social simulations.*
- ✓ *To identify the target population's perspectives on the model of virtual social simulations.*

- ✓ *To identify the relationship between virtual realism and human anxiety in the virtual social simulation.*
- ✓ *To identify the influence of perceptual virtual apparatus in the virtual social simulation and its correlation to human anxiety.*

To accomplish the research aims, this thesis firstly conducted a literature review to explore relevant theory and the issues relating to the design of the fear-provoking virtual reality simulation. Secondly, a virtual social simulation was developed using this theoretical basis, verifying it with a preliminary study that the simulation might provoke anxiety as we expected. Thirdly, several experiments were conducted, varying different conditions of the virtual reality environment in order to identify the influence of the virtual avatar and visual displays in the anxiety-provoking virtual social simulation. Finally, drawing on the results of these experiments, this thesis might be able to suggest a theoretical framework for the construction of effective virtual reality therapy for social-anxiety care.

## 1.2 General Approach

The main paradigm of this research is to bring a subject into an anxiety-provoking situation that is generated by virtual reality technology. The virtual situation is artificially projected in the subject's mind by mediated stimulations, such as interacting with virtual humans or objects. When the subject develops a mental representation of the virtual stimuli as their own environment, they may begin to feel anxiety and attempt to deal with the situation by subtle avoidance plan or safety behaviours. The evaluation of such reactions is the key element in this research, in order to identify the correlation of these reactions with various conditions of virtual stimuli.

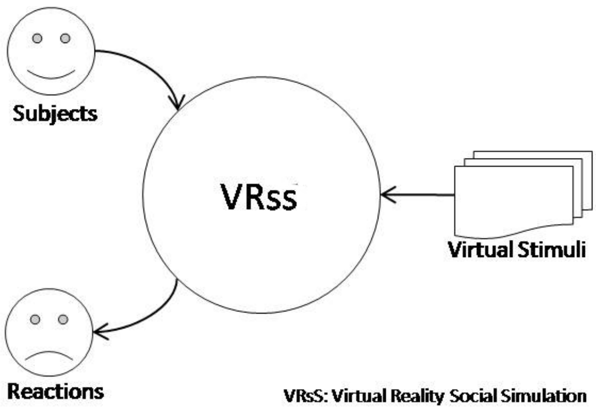



Figure 1.1: General Approach of the Research

By this Stimulus-Organism-Reaction-Consequences (SORC) approach (Blake *et al.*, 2000), this thesis aims to observe and evaluate both human cognition and behaviour, which constrains how people respond to different types of virtual social simulations, using a combination of observational and experimental study (Figure1.1). This mixed approach allows us to attain a full understanding of individuals' behaviour tendencies and their subjective responses to the anxiety-stimulating virtual social simulation.

## 1.3 Thesis Outline

***Chapter 1: Introduction***

This chapter introduces the goal of the research, as well as the general approach.

***Chapter 2: Background***

Chapter 2 describes social anxiety, its definition, characteristics in different aspects, prevalence, and various clinical treatments. In addition, virtual reality technology and the concept of virtual reality's applicability in mental health care are explored. Finally, this chapter conducts a systematic review to evaluate the usage of VR environments, fear-provoking VR stimuli, measurements, and effective size, and to identify theoretical and practical issues for the design of VR applications for social anxiety.

***Chapter 3: Research Methodology***

Chapter 3 describes the scope of investigation, research questions, experiment design, and the strategy of measurements and analysis, as well as looking at the details of our virtual social simulation that was developed on a theoretical basis. In section 3.1, research questions are formulated to define the scope of investigation and to establish a research hypothesis. After that this chapter introduces strategies that were used to design the main experimental studies in this thesis. Our virtual social simulation is detailed in section 3.3. Furthermore, this chapter explain assessment tools that were chosen to measure the level of anxiety. Methods of analysis for each type of data are described in turn. This chapter concludes with a summary of the research protocol.

***Chapter 4: Preliminary Study***

Chapter 4 describes the preliminary study that aimed to identify how well our virtual simulation works to provoke anxiety, and to learn its potential barriers and unpredictable issues for the main experimental study. This study focuses more on the perspectives of the target population on their experience of the virtual social simulation, rather than the comparisons of result variables in statistical methods.

***Chapter 5: Social Anxiety and Visual Realism in VR***

Chapter 5 evaluates the level of realism that was required within the virtual environment, and how the individual's anxiety varied between different graphic fidelities of virtual environments, in order to ensure the environment was effective in helping the participant to deal with their anxiety. An experimental study was conducted with 60 subjects and their anxiety levels are evaluated via repeated measure design, where each treatment was exposed to a different level of fidelity of the virtual avatars.

***Chapter 6: Social Anxiety and Immersive VR displays***

Chapter 6 describes the experimental study that was conducted over 20 subjects, the aim of which was to investigate the impact of different immersive levels of visual display in an anxiety-activating virtual social simulation. This experiment study compares the state of anxiety in fully-, semi-, and non-immersive environments.

***Chapter 7: Thesis Discussion***

Chapter 7 summaries the overall findings of this research, and discuses its potential impact, limitation and issues about its general applicability.

***Chapter 8: Conclusion and Future Work***

Chapter 8 concludes this research and its contribution to knowledge. Future work, unveiled by relevant conclusions, is suggested.

CHAPTER 2

# Background

The fear of social interactions (also called social phobia) has become one of the commonest manifestations of anxiety in society (Fehm *et al.*, 2005). A number of virtual reality researchers or psychologists have explored the use of immersive virtual environments to combat social phobia. For a better understanding of all the issues relating to virtual-reality-based psychological treatments for social phobia care, this chapter begins with an examination of social phobia, including a definition, prevalence, characteristics, symptoms, and conventional clinical treatments (Section 2.1). After a brief introduction to the concept of Virtual Reality (Section 2.2), Section 2.3 explores the theoretical and practical issues of Virtual Reality Exposure Therapy (VRET). In Section 2.4, a systematic review is conducted to look at all the studies that are related to a virtual reality exposure for social phobia care and to present a summary of the findings from the individual studies.

## 2.1 Social Phobia

Social phobia has often been described as individuals experiencing nervousness, anxiety or fear in their relationships with other people (Wells, 2002). Socially anxious people often believe that they are being appraised by others or are made to feel self-conscious by their own attitudes (Deborah *et al.*, 1999). Socially phobic individuals suffer typical anxiety symptoms such as blushing, profuse sweating, trembling, nausea, and difficulty talking (Veale, 2003). Stressful social situations are regularly avoided or endured with intense anxiety (Furmark *et al.*, 1999).

Social phobia is often limited to specific social environments such as formal public speaking, job interviews, and casual conversations, but it can include a wide range of situations (Furmark *et al.*, 1999). By Holt's hierarchical classification (Holt *et al.*, 1992), social phobia can be categorised into four domains: performance (speaking in public), informal speaking (*establishing contacts and small talk*), observation by others (*protecting one's interests, viewpoints, and being respected*), and assertiveness (*acting while being under scrutiny*). Generalised social phobia encompasses individuals suffering anxiety in multiple situations, whereas non-generalised (or specific) social phobia only occurs in one or two feared situations (Holt *et al.*, 1992). In many studies, generalised social phobia is defined as including cases with at least three feared situations, but this number has not been validated explicitly (Wittchen & Fehm, 2003).

### 2.1.1 The Prevalence of Social Phobia

Numerous epidemiological studies have examined the prevalence of social phobia in the general population since its official inclusion in the DSM-III (*the third edition of the Diagnostic and Statistical Manual of Mental Disorders*). In the National Comorbidity Survey, social phobia was a relatively common disorder with an estimated lifetime prevalence of about 13.3% in the United States (Kessler *et al.*, 1998). A recent study, by Fehm, examined the epidemiology of social phobia as defined by modern diagnostic criteria (DSR-III-R or DSM-IV) within European countries only (Fehm *et al.*, 2005). This study suggested that the average prevalence is 6.65% in a median lifetime, and 2.3% in a 12-month period.

This figure can be used to estimate that the number of social phobia sufferers in the UK population (aged between 18 and 65) is 1.2 million out of the UK total population of 60 million within a 12-month period (Wittchena & Jacobib, 2005).

### 2.1.2 The Characteristics of Social Phobia

Social phobia shares common characteristics with the notion of shame (Gilbert & Andrews, 1998). However, social phobia is often accompanied by significant social disabilities (Veale, 2003). The characteristics of social phobia are elaborated by looking in more detail at the cognitive, behavioural and physiological aspects (Lang, 1985).

#### 2.1.2.1 Cognitive Aspects

In terms of the cognitive aspects, Clark and Well (1995) emphasised that individuals with social phobia are excessively concerned about other people's evaluations of them. Social phobia can derive from negative thoughts about perceived individual weaknesses, idealistic beliefs about the standards people usually use to assess others, or an individual's high expectations of their own performance (Turner *et al.*, 1992). Leary and Kowalski (1995) also argued that social phobia is induced when individuals are stimulated to build particular impressions of others but disbelieve their own capability to perform successfully. Clark and Well (1995) suggested a cognitive model of social phobia to explain the process of how social phobics react when in a feared situation (Figure2.1).

When patients enter a social situation, negative assumptions are activated. They believe that they are in danger of negative evaluation, and begin to observe themselves or to monitor the sensations and images. The internal information is associated with feeling anxious or with distorted images. The images are usually correlated to early memories. The somatic and cognitive symptoms and

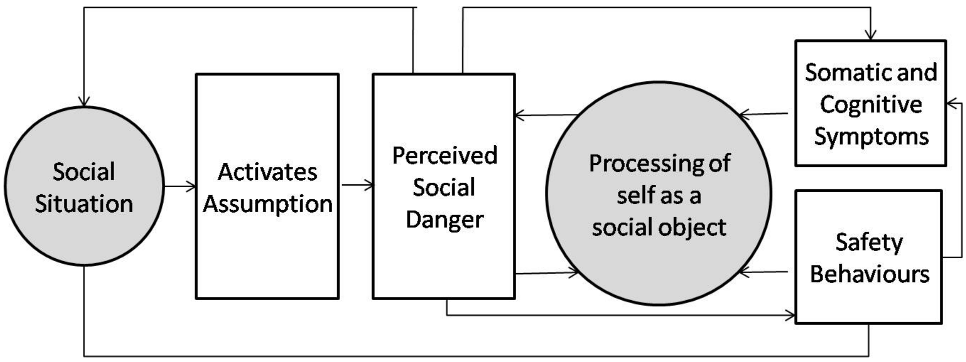



Figure 2.1: The Cognitive Model of Social Phobia (Clark & Wells, 1995)

safety behaviours occur in feared situations. The cognitive symptoms include pessimistic thinking and extreme worry (Salkovskis, 1998). The somatic and behavioural symptoms are explained in the following subsections.

#### 2.1.2.2 Behavioural Aspects

In social phobia, escape and avoidance are well-known behaviours, for example avoiding eye contact when talking with other people, escaping from the anxiety-provoking situations, wearing cool clothes to hide sweating, holding arms rigid to avoid shaking, and so on (Wells & Clark, 1997). Such escape or avoidance behaviours are induced to decrease the danger of social failure, to avoid disconfirmation of negative beliefs, and to protect self-focused attention (Wells & Clark, 1997). In behavioural perspectives on social phobia, the issue of social skills is often mentioned to explain the characteristics of social phobia. Beidel et al. (1985) proposed that social phobia may be induced by the lack of verbal or non-verbal skills that are compulsory to social interactions or performance situations. However, Rapee's study demonstrated that, while an individual's social anxiety may appear to demonstrate an absence of confidence and abilities when in social situations, this might reflect self-consciousness rather than an actual lack of social skills (Rapee, 1995).

#### 2.1.2.3 Physiological Aspects

Social phobics manifest somatic symptoms similar to those observed in other anxiety disorders (Rapee, 1995). Pale skin, sweating, trembling, pupillary dilation, nausea, and chills are examples (Dwight *et al.*, 2005). These arousal symptoms are features of the "*fight or flight response*" and are related to the autonomic (or visceral) nervous system (Dwight *et al.*, 2005). ICD-10 (*International Statistical Classification of Diseases and Related Health Problems 10th Revision*) criteria for social phobia lists the appearance of a psycho-physiological anxiety reaction, such as blushing, hand tremors, nausea, urgency of urination, and so on. Among various autonomic arousals, facial blushing and somatic symptoms of embarrassment are the commonest signs in social phobia (Stein & Bouwer, 1997).

### 2.1.3 Various Treatments of Social Phobia

Various treatments for social phobia have been developed and evaluated since 1980. A huge number of studies have demonstrated the evidence for the effectiveness of pharmacological and psychological treatments, as well as some computer-mediated treatments.

#### 2.1.3.1 Pharmacological Treatment

Selective serotonin reuptake inhibitors (SSRIs) have been used widely for social phobia due to their anti-anxiety effects (Gelernter *et al.* 1991 and Prasko *et al.* 2003). The effectiveness of SSRIs for social phobia treatment has been verified in several randomised controlled trials, for example fluvoxamine (Stein *et al.*, 1999), sertraline (Katzelnick *et al.*, 1995), and paroxetine (Allgulander, 1999). However, D'esor'ee(2001) demonstrated that the drug treatment showed only a small to moderate sized effect on social anxiety and avoidance and this did not reflect a clinically relevant improvement. Gould (1997) conducted a meta-analysis for pharmacotherapy in the treatment of social phobia. The results revealed that pharmacotherapy is less effective than psychological treatment for social phobia (e.g. CBT).

#### 2.1.3.2 Psychological Treatment

Since the 1980s various psychological therapies for social phobia have been developed (Table 2.1), and the effectiveness of these has been widely evaluated. Among possible psychological treatments for social phobia, cognitive behavioural therapy (CBT) is the most popular and commonly used treatment. CBT is a structured form of psychotherapy and encompasses education about anxiety, exposure to feared situations (both imaginal and real-life situations), cognitive restructuring, relaxation training, and homework assignments for in-vivo exposure (Heimberg *et al.*, 1999).

The effectiveness of CBT for social phobia has been demonstrated by several controlled studies. Butler (2001), Rowa (2005) and Scholing (1996) conducted comparative studies to identify the effectiveness of CBT with waiting-list or placebo. The results illustrated that the treatment brought a significant improvement in the short term and also in the long term. In a meta-analysis of 42 studies of psychological therapy on social phobia, Taylor (1996) noted that all interventions reviewed, including placebo, had larger effect-sizes than those of waiting-list controls, but only exposure in combination with cognitive restructuring was significantly better than placebo. Cognitive behavioural therapy showed the highest mean effect size (Hedges' g value = 0.68) relative to the other treatments. Withdrawal rates were also found to be lower for cognitive behavioural therapy: 5.6% compared to 19.8% in pharmacological treatments and 22% in combined treatments (Talyor, 1996).

| Therapy (number of article*) | Description |
|---|---|
| Cognitive Behaviour Therapy (CBT) (692) | CBT helps a person to recognise his or her own negative thought patterns and behaviours, and to replace them with positive ones. CBT is the most popular and commonly used therapy for the treatment of depression and phobia. A major aim of CBT is to reduce anxiety by eliminating beliefs or behaviours that help to maintain problematic emotions (Salkovskis, 1998). |
| Cognitive Behaviour Group Therapy (CBGT) (16) | CBGT is a group-based cognitive behaviour therapy that is conducted with a group of about six to eight patients by two co-therapists every week for about three months. Within the group therapy sessions, patients are exposed to other group members, and receive their feedback. These therapeutic procedures are followed up by homework exercises carried out by the patients during their own daily activities (Heimberg *et al.*, 1990). |
| Cognitive Therapy (CT) (678) | Cognitive therapy seeks to identify and correct thinking patterns that can lead to troublesome feelings and behaviours. Beliefs and expectations are explored to identify how they shape a person's experiences. If a thought or belief is too rigid and causes problems, the therapist helps the client to modify his or her belief (Clark, 2006). |
| Exposure Therapy (ET) (267) | Exposure therapy is a process by which a person is exposed to feared situations or objects. Exposure therapy involves helping patients gradually become more comfortable with situations that frighten them. The exposure process often involves three stages. The first involves introducing people to the feared situation. The second level is to increase the risk for disapproval in that situation so people build confidence that they can handle rejection or criticism. The third stage involves teaching people techniques to cope with disapproval (Haug *et al.*, 2003). |
| Family therapy or Couples therapy (19) | Family therapy includes discussion and problem-solving sessions with every member of the family. Sessions are done as a group, in couples, or one on one. In therapy, interpersonal relationships shared among family members are examined and communication is strengthened. In group therapy, a small group of people meet regularly to discuss individual issues and help each other with problems with the guidance of one or two trained therapists (Barrett, 1996). |
| Interpersonal therapy (139) | Interpersonal therapy (IPT) focuses on an individual's social relationships and how to improve social support. IPT therapy seeks to improve a person's relationship skills, working on communication more effectively, expressing emotions appropriately and being properly assertive in social and work situations (Alden & Taylor, 2004). |
| Rational-emotive therapy (16) | The main purpose of RET is to help people to replace absolutist philosophies, full of 'must' and 'should', with more flexible ones; part of this includes learning to accept that all human beings are fallible and learning to increase their tolerance for frustration while aiming to achieve their goals (Mersch, 1995). |
| Psychoanalysis (10) | Psychoanalysis helps a person look inside himself or herself to discover and understand emotional conflicts that may be contributing to emotional problems. The therapist helps the client uncover unconscious motivations, unresolved problems from childhood and early patterns to resolve issues and to become aware of how those motivations influence present actions and feelings. This is a lengthy process, typically taking several years (Gedo, 1989). |
| Morita therapy (1) | Morita therapy leads patients from preoccupation with and attempts to eliminate neurotic symptoms towards accepting anxiety as natural while engaging in constructive behaviours. The basic theory of Morita includes the naturalness of feelings, that feelings are uncontrollable, and a belief in constructive actions as opposed to analytically identifying and labelling problems (Yamashita, 2002). |

*Method: All abstracts were collected from MEDLINE, EMBASE, PsyINFO, CINAHL, IBSS, Cochrane Library, and electronic journals with two combined search concepts: psychological therapy and social phobia. All citations were included, in English language, from 1980 to 2008, peer reviewed journals and dissertations, and government reports. 1838 out of a total of 3887 articles mentioned specific therapies for social phobia care, and this number does not include pharmacological or computer-mediated therapy

Table 2.1: Various Psychological Therapies for Social Phobia

#### 2.1.3.3 Computer-Mediated Treatments

Recently, a number of studies have used a computer as a medium for social phobia care. The Internet (Kenwright *et al.*, 2001), Multimedia (Proudfoot *et al.*, 2003), Palm-PC (Przeworski & Newman, 2004), and Virtual Reality (North *et al.*, 1998) are examples. The computer can be applied to diagnose psychological symptoms and to manage in-vivo exposure, in addition to providing treatments. It can deliver a diversity of treatment through the internet, an interactive telephone, or a virtual reality system (Kaltenthaler *et al.*, 2008). As Butler and Wells (1995) point out, all these methods have been effective, at least to some degree, although their relative values are difficult to determine because of differences in study designs, outcome measures, patient selection, and comparisons made.

Using virtual reality as a therapeutic tool has distinct benefits. Unlike other computer-mediated therapies, Virtual Reality Exposure Therapy (VRET) has a number of advantages and has enabled exposure therapy to overcome some of the difficulties inherent in traditional in-vivo or imaginal treatment (Vincelli & Molinari, 1998), for example the capacity of re-experiencing or reliving the past (Difede & Hoffman, 2002), through monitoring a patient's movements or signals with visual outputs (Riva, 1997), controllable stimuli in real time (Rizzo & Kim, 2005) and location of patients in an environment, allowing for multiple situations without any travelling, with no public embarrassment, and with lower expenditure (North *et al.*, 1997).

## 2.2 Virtual Reality

A new computer-interaction paradigm has been introduced in the form of VR whereby an individual no longer simply observes images on a computer screen but becomes actively involved in a 3D virtual world perhaps incorporating an auditory, olfactory, and tactile approach (Bangay & Preston, 1998). The first concept of virtual reality was devised by Heilig in 1962 (Heilig, 1962). Three years later Sutherland proposed "*Ultimate Display*" in order to allow users to be fully immersed in a computer-generated world. In 1985, NASA's Ames Research Centre introduced the first true virtual reality system (Figure 2.2) (Mario *et al.*, 2008). The system consisted of a wide-angle stereoscopic display unit, glove-like devices for multiple degrees-of-freedom tactile input, speech recognition technology, gesture tracking devices, 3D audio, speech synthesis, computer graphics, and video-image-generation equipment (Mario *et al.*, 2008). Since then, virtual reality technology has been developed in many forms to become an emerging technology of our time. Most recently, Chalmers et al. (2009) introduced a five-sense stimulating head-mount display which they term a "*Virtual Cocoon*" (Figure 2.3).

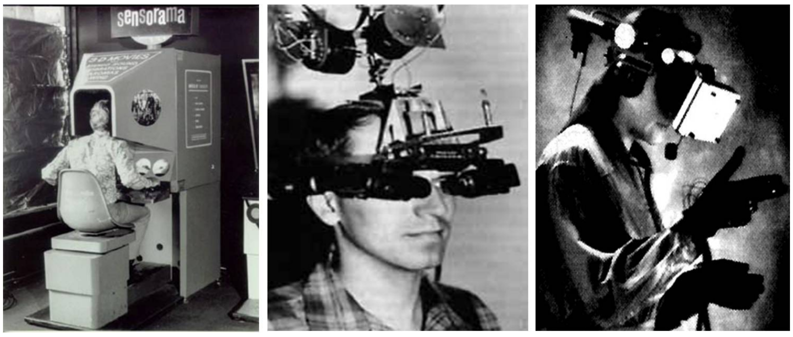



Figure 2.2: Virtual Reality Systems (from left to right): Heilig, Sutherland, and NASA. (NASA)


Figure 2.3: The Five-sense Virtual Cocoon System. (IDL, WMG)

### 2.2.1 Definition of Virtual Reality

As virtual reality is still an ongoing project, no clear definition exists, but various definitions have been suggested by researchers and users. Most definitions of virtual reality usually make reference to a particular technological system that encompasses three-dimensional models, computer-generated objects or scenes, a set of wired gloves or a position tracker, and a stereoscopic display for visual outputs. The following contains several examples of such definitions:

- ✓ Satava (1993): "*The term of virtual reality can be defined as a high-quality of human-computer interaction concept, in which people are the active participants in a computer-generated three-dimensional environment. This is accomplished by totally immersing the person's senses using a head-mounted display (HMD) or some other immersive display devices, and an interaction device such as a data-glove, a position tracker or a joystick.*"

- ✓ Riva (1997): "*Virtual reality is a set of computer technologies which, when combined, provide an interface to a computer-generated world. In particular it provides such a convincing interface that the user believes he is actually in a three-dimensional computer-generated world. A virtual environment is a virtual reality application that lets users navigate and interact with a three-dimensional, computer-generated environment in real time.*"

- ✓ Gigante & Earnshaw (1993): "*VR relies on three-dimensional, stereoscopic head-tracker displays, hand/body tracking and binaural sound. VR is an immersive, multi-sensory experience.*"

- ✓ Cruz (1993): "*Virtual reality refers to immersive, interactive, multi-sensory, viewer-centred, three-dimensional computer-generated environments and the combination of technologies required to build these environments.*"

From a psychological point of view, VR makes the user believe that "*he/she is there*" (Kelly, 1989). This feeling of presence distinguishes VR from interactive computer graphics or other types of multimedia (Rothbaum *et al.*, 1995). By providing a sense of presence to users, the users become a part of the virtual world. Such a paradigm has been utilised by various types of virtual reality applications relating to all areas of human activity (Rothbaum *et al.*, 1995). Training simulators are one of the most successful examples of VR applications. The virtual training simulation allows an individual to develop existing cognitive and motor skills through interaction with a wide range of sensory devices and the experience learned in the virtual environment is directly transferable to the real world (Gobbetti & Scateni, 1998).

### 2.2.2 Virtual Reality Experience

The concept of VR experience is based on the human perception of the extent to which people feel a sense of "*being there*" in a virtual world (Slater & Usoh, 1995). There are two main factors characterising the VR experience from the psychological and physical points of view, which are Sense of Presence (SoP) and Immersion (Mario *et al.*, 2008).

#### 2.2.2.1 The Sense of Presence

VR experience is often explained by the sensation of "*being there*". The feeling of being in the VR is also called the Sense of Presence. The SoP is discussed in various literatures related to VR with reference to Slater and Wilbur's definition: "*Presence is a state of consciousness, the sense of being in the virtual environment*" (Slater & Wilbur, 1997). There are several definitions and theories to describe the notion of SoP from different points of view.

*The Theory of Presence*

In media and emergent technologies, the sense of presence is generally defined as the perceptual illusion of non-mediation (Lombard & Ditton, 1997). An illusion of non-mediation occurs when the users fail to recognise the existence of a medium in their communication environment and react as they would if the medium were not there (Lombard & Ditton, 1997). Lombard and Ditton proposed six different conceptualisations to explain the sense of presence, as follows:

- ✓ *Social richness* - The degree in which a medium can be perceived as social, warm, or personal.
- ✓ *Realism* - The degree in which a medium can accurately produce objects, events and people
- ✓ *Transportation* - The degree in which a medium can transport a user to another place.
- ✓ *Immersion* - The degree in which a medium can engage a user to the mediated environment.
- ✓ *Social actor within medium* - The degree in which a medium can be socially responded to a representation of a person through a medium.
- ✓ *Medium as social actor* - The degree in which a medium can be perceived as a social actor.

Focusing on the SoP in virtual environments (VEs), Slater and Wilbur (1997) proposed the difference between presence (*human responses to the system*) and immersion (*physical reality*) in VEs. Presence is a subjective phenomenon, such as the sensation of being in VEs, and immersion is an objective description of aspects of the system, such as field of view and display resolution (Slater & Wilbur, 1997). Furthermore, IJsselsteijn *et al.* (2000) argued that the SoP in VEs can be distinguished from social presence (*the feeling of being there*) and physical presence (*the feeling of being physically located in a place*). According to their definitions, the SoP can be described as the experience of being in VEs rather than the actual physical surroundings.

Heeter (1992) suggested the dimensions of presence, proposing three different types: *Personal Presence*, *Social Presence*, and *Environmental Presence*. Personal presence describes a measure of the extent to which an individual believes in being in the VEs. Social presence is the extent to which multiple individuals believe in being in the VEs. Environmental presence explains the extent to which the environment itself acknowledges and reacts to the individual in the VEs. From a different point of view, Schloerb (1995) characterised the SoP by two different types of presence in VEs: *Subjective Presence* and *Objective Presence*. Subjective presence is defined as the possibility that the individual evaluates himself to be physically present in the remote or virtual environment. Objective presence is produced by the possibility of successfully achieving a task.

Furthermore, Zeltzer's taxonomy of VEs has often been cited to explain the notion of SoP as a method of evaluation for VEs (Zeltzer, 1992). He proposed that VEs can be characterised by three main components: Autonomy (*the extent to which the VE is more than just passive geometry*), Interaction (*the degree to which VE parameters can be modified at runtime*), and Presence (*the measure for the number and fidelity of available sensory input and output channels*). The correlation between the three components can be drawn as a cube (Figure 2.4).

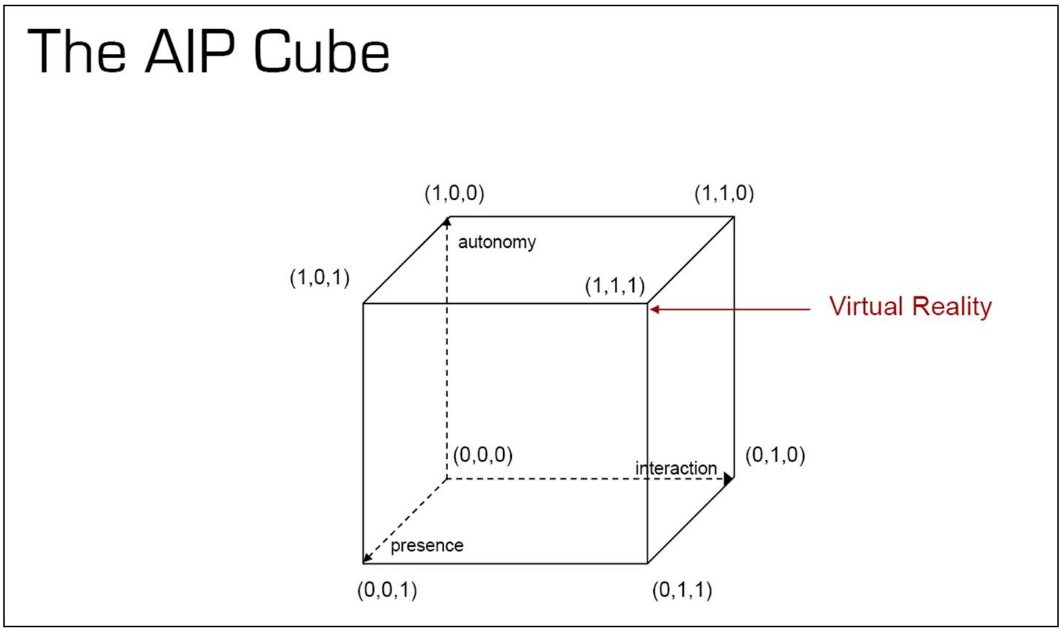



Figure 2.4: AIP Cube (Zeltzer, 1992)

*The Cause of Presence*

Most researchers have verified that the SoP is interrelated to perceptual and psychological aspects. Schuemie *et al*. (2001) summarised previous research and their findings about the aspects of the cause of presence in VEs. Table 2.2 below reproduces this summary of the presence-provoking factors, adding several studies that were absent from Schuemie et al.'s analysis.

| Authors | Factors |
|---|---|
| Slater & Usoh (1995) | ✓High-quality, high-resolution information ✓Reliability across all displays ✓Interaction with environment ✓Effect of predictable actions |
| Slater *et al.* (1995) | ✓Dynamic shadows |
| Witmer & Singer (1998) | ✓Control factors ✓Sensory factors ✓Distraction factors ✓Realism factors |
| Sheridan (1992) | ✓Extent of sensory information ✓Control of relation of sensors to environment ✓Ability to modify physical environment |
| Steuer (2003) | ✓Vividness ✓Interactivity ✓User characteristics |
| Lombard & Ditton (1997) | ✓The content of the information ✓User characteristics |
| Welch *et al.* (1996) | ✓Pictorial realism of a virtual environment ✓Visual feedback ✓Observer interactivity |
| Wilson *et al.* (1997) | ✓Visual depth cues ✓Cyber-sickness |
| Sadowski & Stanney (2002) | ✓Ease of interaction ✓User-initiated control ✓Pictorial realism ✓Length of exposure ✓Social factors ✓Internal factors:individual difference ✓System factors: system design |
| Barfield & Weghorst (1993) | ✓Display technology ✓Immersion ✓Sensory fidelity ✓Attentional resource |
| Heeter (1992) | ✓User's personality ✓Movement and navigation ✓Feedback |

Table 2.2: The Factors of the Cause of Presence

#### 2.2.2.2 Immersion

The concept of immersion is strongly related to the technology that allows users to experience a continuous stream of stimuli by the interaction with multimodal sensory inputs (Draper *et al.*, 1998; Witmer & Singer, 1998;Slater & Wilbur, 1997; Ellis, 1991). For example, Ellis (1991) defines immersion as "*consisting of content, geometry and dynamics, with an egocentric frame of reference, including perception of objects in depth, and giving rise to the normal ocular, auditory, vestibular, and other sensory cues and consequences.*" In addition, Slater and Wilbur (1997) describe the concept of immersion as "*the extent to which computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the sense of the VEs participant.*" These definitions indicate that the concept of immersion is a physical configuration of the user interfaces in a VR system rather than a psychological characterisation of what the system supplies to the human participant.

Immersive virtual reality is often classified into fully immersive (*head-mounted displays*), semi-immersive (*large projection screens*), and non-immersive (*desktop-based VR*) (Kalawsky, 1996). This classification depends on how much the individual can perceive the VEs as a real world. Figure 2.5 shows VR displays and their immersive levels.

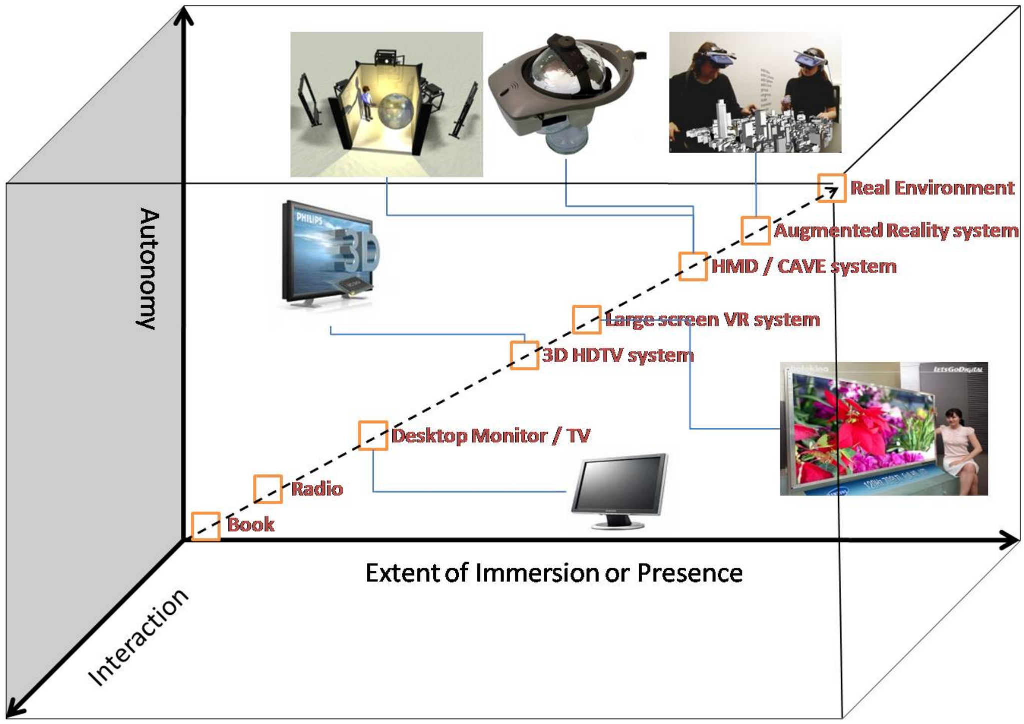



Figure 2.5: Immersive VR Systems (Kalawsky, 1996)

The typical fully immersive system is a head-mounted display (HMD). The HMD has a stereoscopic display (*two small displays*) and speakers in a helmet, as well as a sensor for head movement tracking. The displays deliver slightly different images to each eye, and users perceive depth and dimension. The head tracking sensor allows the user's view of the virtual world to change in correspondence with the head movements made in the real world. These combinations of technology create a sense of inclusion within a virtual world, and fully isolate the user from the outside of the simulated environment (Mario *et al.*, 2008).

A semi-immersive system, such as a large projection, provides 3D sound and high-resolution graphics. A large projection is a multi-user workplace surrounded by screens onto which the virtual world is projected. Images are displayed according to the position and gaze direction of the main user. In general, a semi-immersive system lets several users share the simulation; this opens up interesting possibilities for collaborative work (Mario *et al.*, 2008).

Non-immersive systems have gained popularity due to their lower cost, ease of use, and ease of installation. They are sometimes called desktop-based VR systems; the most representative examples are video games. The combination of interactivity, ease of use, and appealing graphics and sound can produce in the users a great level of interest and involvement in the simulation (Mario *et al.*, 2008).

### 2.2.3 Technology of Virtual Reality Systems

Most current VR technology consists primarily of visual experiences, displayed either on a computer screen or through special stereoscopic displays, but some simulations include additional sensory information, for example sound through speakers or headphones, and some advanced haptic systems now include tactile information. The virtual reality system allows users to interact with the virtual environment through the use of standard input devices such as a keyboard and mouse, or through multimodal devices such as a wired glove, a boom arm, and an omni-directional treadmill. Figure 2.6 shows several examples of virtual reality systems that appear in diverse forms according to different hardware and software.

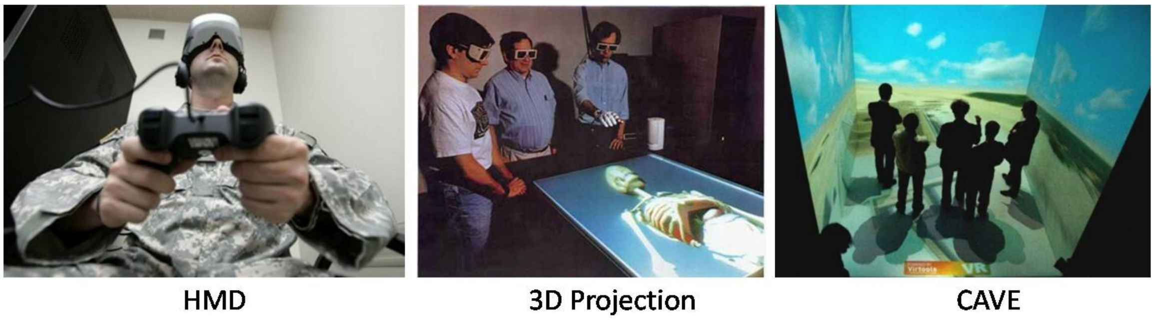



Figure 2.6: Examples of Virtual Reality Systems

#### 2.2.3.1 VR Applications: Basic Components

A VR system requires more resources than a standard desktop system. Additional input and output devices and special drivers for them are needed for enhanced user interaction. Figure 2.7 shows a basic VR system architecture. The VR system consists of five main components: VR engine, Software and Database, I/O devices, User, and Task.

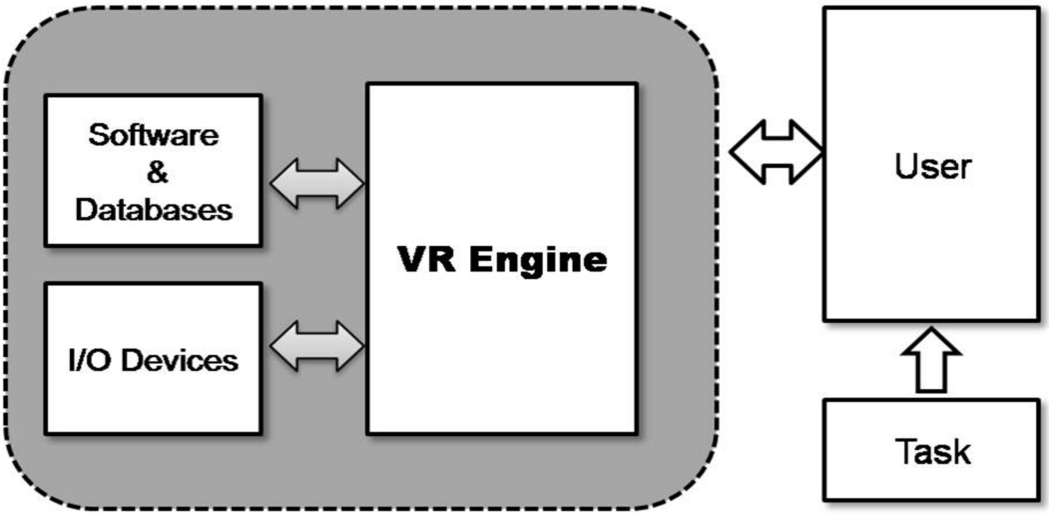



Figure 2.7: Basic VR System Architecture (Burdea, 2006)

There is a vast array of possible software and hardware to generate various forms of virtual environments. Rather than describing existing VR technology in its entirety, VR software and hardware is briefly introduced below.

#### *VR Engines*

The VR engine is a main component in generating VR environments. It is a platform for rendering VR objects or scenes and communicating with VR in/output peripherals such as HMDs, motion trackers, data gloves, joysticks and so on. The VR engine abstracts hardware and software complexities in the system thereby allowing users to write applications without having to know every detail of the system (Burdea, 2006). The most common examples of VR engines are Virtools, Ogre 3D, VHD++, DIVE, and DirectX SDK.

#### *Input Devices*

A VR system requires data from the user's inputs in order to provide rich human interaction. The VR system receives input from tracking systems, gloves, digital input devices, and a wide variety of other devices. Head trackers and data gloves are commonly used in virtual reality systems (Figure 2.8). A head tracker is a head positional input device that provides data about the location of the user in space. This tracking system is composed of a device called a tracker and a base unit. The tracker can be directly attached to the user, or to other devices (e.g. HMD). The base unit remains stationary so that the tracking software can use it as a reference point for calculating the position of the tracker (Burdea, 2006). In addition, data gloves can recognise hand information that provides visual feedback or performs conflict detection. In most cases, the hand information is given to a piece of gesture-recognition software. This software allows the system to recognise the user's body movements in order to interact with an application (Burdea, 2006).

Figure 2.8: VR Input Devices (from left to right): Motion Tracker, Data Glove, Space Ball

### ***VR Display Systems***

Head-mounted display (HMD) is a single-user-based visual display system. It has two small displays and semitransparent mirrors embedded in a helmet, eyeglasses, or visor. Many HMDs include speakers or headphones to provide both video and audio output. HMDs almost always comprise a tracking device that can display users' views according to their head movements. HMDs can completely isolate the user from the real world, and longer exposure with HMDs may cause simulator sickness and physical discomfort (Mario *et al.*, 2008).

Computer automatic virtual environment (CAVE) is a multiuser projection-based VR system. In the CAVE system, multiple users are surrounded by stereoscopic computer-generated images on four to six sides (*A cubicle*). The users wear shutter glasses that lighten and darken in synchronisation with the images on the screens. An electromagnetic tracking system is used, and a sensor is attached to the user's shutter glasses to generate a correct perspective view. The user can walk naturally and freely through the system within the limits of its space (Mario *et al.*, 2008).

In addition, there are several sensory displays, such as auditory (*3D speaker*), haptic (*force-feedback*), and olfactory displays (*Air-cannon*). These sensory displays provide more advanced immersive virtual environments, but are still under-developed, particularly in olfactory and gustatory displays (Basdogan & Loftin, 2008).

#### 2.2.3.2 Human Factors

VEs are regarded as being systems that enhance human computer communication by simulating natural human interaction through appropriate simulation of sensory channels (Stanney *et al.*, 1998). A number of researchers have studied the essential factors of being the user of the VR system to understand human abilities and limits in VR sensory channels. This section reviewed the commonest issues of human factors in the virtual environment.

***Human Sensory Limitation***

VR system designers have always been concerned with human sensory issues that directly impact upon the design of virtual environments, including visual, auditory, haptic, gustatory and olfactory perception.

Visual display is a frequently considered issue in the development of VEs, because the human's visual system is more sensitive to an experience than the other senses (Larijani, 1994). HMD provides stereo images to both eyes, thus adjustments for the inter-pupillary distance (IDP) are critical. IDP is the distance between the centres of pupils which clearly has an influence on the stereo perception that is produced from the two separate images. However, the IDP is always varying in accordance with differing age, gender and race. Hence, identification of the mean of IDP for production of stereoscopic content is essential (Dodgson, 2004).

Furthermore, the user's visual field ability is one of the disputable issues of HMDs, due to the differences between individuals. Existing HMDs are usually restricted up to a field of view (FOV) of 100 degrees per eye, which is insufficient to meet humans' FOV ability (*140 degrees*) (Biocca, 1992b). Biocca (1992b) also noted that FOV in HMD has an impact on the resolution of the projected images. If the FOV is expanded, the resolution declines. Moreover, Pausch *et al.* (1992) demonstrated that wider FOVs have an influence on the feeling of motion sickness. Thus, there is an essential requirement to determine what FOV is needed to achieve various types of VE tasks successfully.

The issue of stereopsis is another physiological matter in VEs (Ellis & Bucher, 1994). In HMDs stereopsis is the main technique and explains visual perception that brings about the sensation of the two monocular images seen by the eyes in depth. It is commonly referred to as depth perception. Current HMDs appear to have problems, particularly smaller and lighter HMDs, which have low levels of stereopsis. Thus, it is essential to determine what levels of stereopsis are needed in order to develop VR applications (Mon-Williams & Wann, 1992).

As far as auditory perception is concerned, the technology of auditory display is the most developed field in VR environments. Current auditory displays utilise the technique of Head Related Transfer Function (HRTF) that is grounded in the knowledge of the source position. This approach can be corresponded to the change of sound sources as a listener's head moves (Cohen, 1992). More advanced HRTF has been developed to cover the issue of personalisation (Engineering *et al.*, 1995). However, limitations still exist in the personalised functions, which require a significant amount of calibration time (Engineering *et al.*, 1995).

Haptic perception is always related to mechanical contact with the skin. Burdea and Coiffet (1994) have found that haptic feedback allows users to enhance their performance in the VR environment. However, human skin has changeable thresholds for touch as well as an ability to perform complex spatial and temporal summations that are all a function of the type and position of the mechanical stimuli; for these reasons, the attributions of skin are difficult to characterise in a quantitative research (Hill, 1967). Moreover, the sensitivity of the skin is decreased in continuous stimulus, although the stimulus is still present. Current haptic displays are limited to hands only; for instance, electrotactile and vibrotactile apparatus have been developed to simulate the feeling of textural illusions on the hand (Stanney *et al.*, 1998).

In issues of olfactory or gustatory perception in VR environments, there are a limited number of effective displays in existence due to the difficulty in generating a wide range of odour or taste stimuli. Smell can be detected in sparse awareness and also recognised in very large quantities. However, the sensitivity is temporary and response times are slow (Basdogan & Loftin, 2008). In addition, taste can be varied because of differing human abilities to discern a specific taste and agree on a characterisation of that taste. Human variability in taste and smell is large, thus no effective display for olfactory or gustatory perception exists.

#### *User Characteristics*

Lampton *et al.* (1994) noted that the characteristics of the user have a considerable influence on VR performance. The understanding of user characteristics is important to design VEs that take into account these unique requirements of users. Several studies discovered the factors influencing VEs, for example the level of experience (Eberts, 1994), cognitive abilities (Stanney & Salvendy, 1995b), personality (Egan, 1988), age (Egan, 1988), and perception and cognition (Salthouse, 1992). Barfield and Weghorst (1993) demonstrated the impact of these factors on the sense of presence. Moreover, Parker and Harm (1992) reported cyber-sickness experienced by VE subjects.

#### *Health and Safety Issues*

There are several health and safety issues that may affect users of virtual environments. Two general categories of VR-related side effects have been reported: direct effects and indirect effects (Stanney *et al.*, 1998). The direct effects include cyber-sickness or trauma. The indirect effects include physiological after-effects. Cyber-sickness is a form of motion sickness that occurs as a result of exposure to VEs. Users of VEs often experience various levels of sickness, ranging from a slight headache to an emetic response. However, most user studies for VEs have reported minor symptoms of cyber-sickness, and only a few subjects have experienced moderate or severe malady (Regan, 1993).

In the case of physiological after-effects from VR exposure, studies have reported symptoms such as flashbacks, illusory climbing and turning sensations, perceived inversions of the visual field, reduced motor control (Kennedy *et al.*, 1992), reduced complex psychomotor flexibility (Lampton *et al.*, 1994), a disturbed vestibulo-ocular reflex (VOR) function (Hettinger *et al.*, 1987), postural disturbances (Kennedy *et al.*, 1993), and increased risk of adverse adaptations to subsequent normal environments (Regan, 1993). All these studies found that the appearance of after-effects is strongly related to the adaption of users in VEs which are a poor reproduction of the real world, and such various after-effects in VEs can be decreased by repeated exposures to VEs and by more optimal degrees of user controls for movements in VEs (Kennedy *et al.*, 1992; Regan, 1993;Lampton *et al.*, 1994).

## 2.3 Virtual Reality Exposure Therapy

Virtual reality is now beginning to emerge as a possible tool for psychotherapeutic applications, commonly called Virtual Reality Exposure Therapy (VRET). In the early 1990s, Tart (1990) proposed the potentiality of VR as a therapeutic form of consciousness offering "*intriguing possibilities for developing diagnostic,* *inductive, psychotherapeutic, and training techniques that can extend and supplement current ones.*" Since then, North *et al.* (1995) devised the world's first virtual reality system for therapeutic purposes and successfully demonstrated its potential benefits in psychotherapy. The rationale behind its use is very simple: a phobic individual is intentionally confronted with the feared stimuli in a controlled VR environment which involves helping him/her gradually adapt to these conditions. Through the processes of habituation and extinction, he/she can build self-confidence and be better equipped to handle his/her psychological struggles (Riva, 2005).

### 2.3.1 The Principle of Virtual Reality Exposure Therapy

The use of VR as a fear-provoking system is based on its characteristic of perceptual illusion: the sense of presence. According to Riva & Wiederhold (2002b), the VR experience can help psychological therapy because of "*its capability of reducing the distinction between the computer's reality and the conventional reality.*" In addition, Vincelli *et al.* (2001) described VRET as an imagery system that is as effective as reality in inducing emotional responses.

Huang and Alessi (1999) indicated that: "*Like emotions, presence is continuously changing and dynamic, influenced by physiological self perceptions, cognitive self descriptions, and recursive interactions of these variables with the environment.*" The following figure 2.9 illustrates their theoretical representation of the human state and the SoP. The human state could be reciprocally interacted with both the SoP and the time of exposure in a virtual environment.

Several case studies have been conducted to verify the relationship between the SoP and emotional state. These studies reported that the sense of presence is strongly related to emotional reactions. Banos *et al.* (2004) indicated that subjects who experienced a strong feeling of presence reported stronger positive

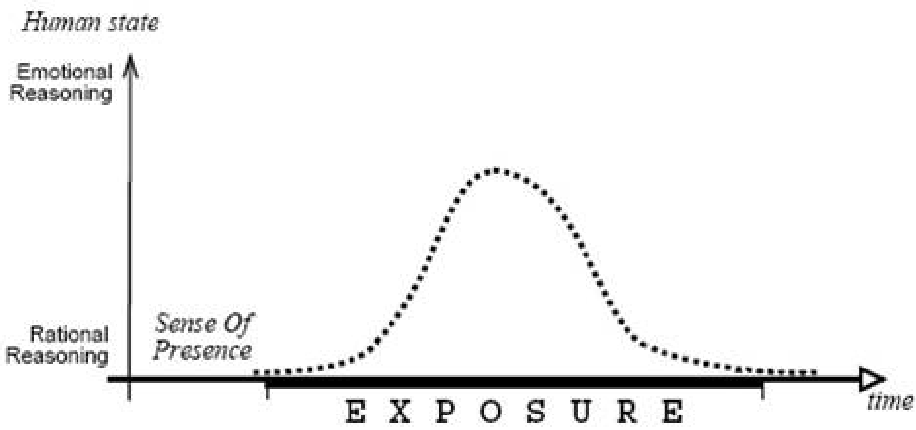



Figure 2.9: The Human State and The SoP During an Exposure (Herbelin *et al.*, 2002)

emotional responses. Schuemie *et al.* (2000) demonstrated the strong correlation between fear and presence. In addition, Regenbrecht *et al.* (1998) investigated the correlation between the SoP and the feeling of fear, both measured by self-report questionnaires. The study indicated that there was no significant difference between them.

With the theoretical foundation of emotional experience in VEs, there are two different perspectives on the principle of VRET: *the emotional processing based model* and *the neurophysiological information processing based model*, both widely accepted in VRET research.

#### 2.3.1.1 Emotional Processing Based Model

The model of emotional processing was first devised in Lang's study, which proposed the conceptual framework of fear-relevant imagery for the background of behaviour therapy in fear reduction (Lang, 1977). Lang's conceptual framework supposed that fear is represented in memory structures that encompass the information of stimuli, responses, and meaning. The memory structures act as a system to avoid or escape from the source of danger (Foa & Kozak, 1986). For example, the fear structure of an individual with cynophobia (e.g. dog phobia) comprises images of dogs (e.g. dangerous), fear responses (e.g. increased heart rate or swearing), and meanings linked with both the information of stimuli and the individual's psychological and behavioural responses.

Conventional psychotherapeutic techniques such as imaginal and in-vivo exposure therapy have used the concept of emotional processing to activate and adjust the fear memory structure (Foa & Kozak, 1986). Imaginal exposure encourages a patient to relive the fear experience through the verbal description of emotional details of the trauma. On the other hand, the in-vivo exposure technique simply places patients in a feared situation to produce anxiety responses. By this fear-activating technique, patients can learn tactics of thought disruption from a therapist. The continuous use of this procedure helps patients to build self-confidence and be better equipped to manage their psychological struggles (Riva *et al.*, 2002).

As a parallel to imaginal or in-vivo exposure techniques, VRET is used as a fear-structure activating system. VRET can progressively immerse patients in a specific feared situation, and modify a patient's fear structure through the habituation and extinction processes (Anderson *et al.*, 2003).

#### 2.3.1.2 Neurophysiological Information Processing Based Model

Rizzo *et al.* (1998) proposed the neurophysiological information processing model to explain the principle of VRET. The approach of neurophysiological information processing is to comprehend patients' patterns of cognitive processes through the monitoring of psychophysiological responses (Rizzo *et al.*, 1998). VRET offers the potential for a human performance monitoring environment in real-time that could enhance conventional neuropsychological procedures. The advanced monitoring environment provides various functions such as supporting in deciding a diagnosis, assisting in producing instructions for the development of treatment plans, and collecting behavioural data for methodical understanding. This information could be used to restructure patients' disturbed beliefs (Rizzo *et al.*, 1998).

### 2.3.2 The Usefulness of VR in Mental Healthcare

Virtual reality exposure therapy (VRET) is becoming widely accepted by clinical society given the great potential that it offers (Riva, 2005). VRET provides a number of advantages in comparison to conventional in-vivo or imaginary exposure therapy (Pull, 2005). VR therapy offers three major therapeutic benefits: monitoring a patient's reactions at the same time as diagnosing symptoms (Rose, 1996), controlling multiple anxiety-provoking stimuli (Riva, 1997), and allowing patients to have effective therapy within the therapist's room, which enables them to avoid dangerous or inaccessible situations (North *et al.*, 1997).

#### 2.3.2.1 Monitoring

VRET may be the most efficient method for monitoring and measuring a patient's behaviours within a systematically controlled stimulus environment (Rose, 1996). Patients are able to induce naturalistic responses when they perceive in a realistic virtual scenario (Sohlberg & Mateer, 2001). The responses can be observed by the VR system with various tracking devices which translate the user's movements into visible information that is presented on the therapist's computer screen.

#### 2.3.2.2 Flexibility of Stimuli Controls

VRET has a capacity to provide and control fear stimuli in a systematic manner, and in a way that is not possible in the real world (Riva, 1997). This fundamental strength of VRET enhances the possibility of obtaining important target responses (Rizzo *et al.*, 1998). Although these features may be possible in a traditional multimedia-based intervention (e.g. Video), VRET offers the ability to control multiple stimulus parameters in real-time which are embedded in immersive simulations of real-world environments (Rizzo & Kim, 2005). In addition, it can provide the capability to isolate the explicit stimuli which influence the dysfunctional response (Riva & C.Botella, 2004).

#### 2.3.2.3 Location

VRET is a set of computer systems and thus patients can experience the feared situation within the privacy of a room. This feature allows patients to deal with the feared situation at their own pace and to feel safe from any public embarrassment. In addition, it means that patient and therapist do not need to travel, which can lead to a reduction in expenditure and time compared to in-vivo settings (North *et al.*, 1998).

### 2.3.3 Limitations of VRET

Despite such promising clinical benefits (Section 2.3.2), several limitations have been discussed in previous research. These can be divided into three broad categories: technical limitations, after-effects, and implementation of VR in mental health.

#### 2.3.3.1 Technical Limitations

The development of the virtual environment itself has several limitations due to its technical complexity. As discussed in Section 2.2.3.2: *Human Sensory Limitations*, VRET also has boundaries to the sensory displays such as device sensitivity, human variability, and side-effects. Inexpensive HMDs are mostly confined to image resolution and field of view. The mechanism of stereoscopy is still problematic, because of its conflict between flat displays and human eye adjustment (Biocca, 1992b). While some high-tech VR displays (e.g. CAVE) may reduce the typical problems of stereoscopy, these extensive VR systems are still high-priced and confined to the scope of potential experiences among mental health researchers (Huang *et al.*, 1998). The development of other sensory displays for smell and touch is comparatively slow in the VR industry, because these apparatus involve a large mechanical configuration, and still face a number of challenges with regard to user variability, distraction, difficulty in producing a broad range of stimuli, and costs (Rizzo & Kim, 2005).

Furthermore, it is true that a virtual environment still has a limited capacity to mimic all the subtleties that are present in the real world. Although the capability of graphic processing (e.g. rendering 3D objects) has been rapidly improved with developing hardware technology over the past few years, such graphic processing units (GPU) are still restricted in terms of generating high-fidelity graphic details of virtual scenes in real-time performance (Rizzo & Kim, 2005).

#### 2.3.3.2 After-effects in VRET

The occurrence of side effects is a critical issue when considering the use of VEs as a mental health application. As discussed in Section 2.2.3.2: *Human Sensory Limitations*, after-effects often include symptoms such as postural instability, flashbacks, tiredness, visual fatigue and generally lowered arousal (DiZio & Lackner, 1992). Thus, clinical users may have more susceptibility to VE-related side effects (Rizzo & Kim, 2005). Ethical consideration to these issues is necessary, and more investigation is required within clinical populations.

#### 2.3.3.3 Issues in Mental Health Research

The Diagnostic and Statistical Manual (DSM-IV) includes phenomenological criteria rather than the features of fear-stimulating environments. Thus, the following questions always become an issue in the development of VRET due to the lack of information in DSM-IV: what elements in a virtual human are the most appropriate in VRET to effectively provoke fear of social interaction, for example appearance, gender, speech tempo, attitudes, graphic details, the manner of communication and so on; and how can a patient's cognitive ability or wish for social interaction in the virtual world be changed? (Huang *et al.*, 1998) In order to overcome this barrier, (Huang *et al.*, 1998) suggested that it is essential to develop a design manual for VRET with collaborative work between mental health researchers and virtual reality researchers. Furthermore, VRET developers have often been concerned with the status of the clinician when applying VR technology for therapeutic purposes (Rizzo & Kim, 2005). Although most of the VR developer community consider that VRETs are merely tools to extend the clinician's expertise, there is also a view among some clinicians that any technology challenges the clinical relationship (Rizzo & Kim, 2005). The issue of VR technology acceptance within the clinical community will probably be addressed in the end if VRET continues to demonstrate effectiveness and added value (Rizzo & Kim, 2005).

## 2.4 Systematic Review: VRET for Social Phobia

The aim of this section is to identify previous studies in which virtual reality was used for social phobia, and to review the effectiveness of VRET. A systematic review was employed to address the aims. This review presents an impartial summary of the findings from the extant literatures within the following four topics: 1) The usage of VR environments, 2) Fear-provoking VR stimuli, 3) Measurements, and 4) Effective size.

### 2.4.1 Methods

All papers were collected from bibliographic databases covering both medical and psychological disciplines, including MEDLINE, EMBASE, PcyINFO, CINAHL, IBSS, Biotechnology, and Blackwell, with two combined search concepts: "*virtual reality*" and "*social phobia*". The review was focused on social phobia or social anxiety disorder and therefore did not include general phobia. However, subtypes of social phobia were included (e.g. the fear of public speaking, or job interview phobia). All citations were included, in English language, from 1990 to 2008, but conference papers and dissertations were not included. When there were several papers concerning the same study, these papers were grouped together and treated as one study.

From all online databases combined by a bibliographic management package, a total of 44 abstracts were recognised. Forty-one relevant studies were selected from the databases by applying the inclusive criteria. Three articles were additionally collected from their references and grey literatures. As a result, 13 studies were finally selected for this review, after excluding duplicated abstracts (n=2), review papers (n=2), and studies that were not related to VRET for social phobia (n=27) from the total number (Figure 2.10).

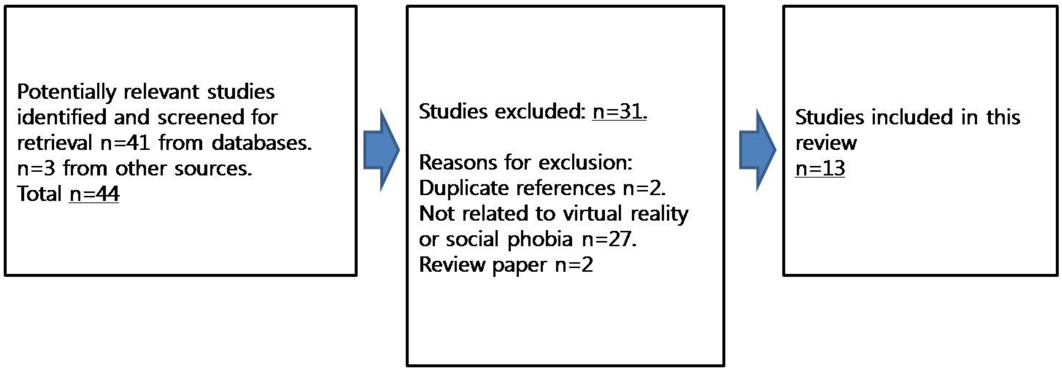



Figure 2.10: Selecting Procedure for Relevant Studies

### 2.4.2 The Usage of VR Technology for the Development of VRET for Social Phobia

The studies in this review utilised various hardware and software to construct a VRET for social phobia. Table 2.3 shows the summary of VR techniques that have been employed for their VRETs.

Nine out of a total of 13 studies used HMD systems as the main technology to immerse participants in the virtual environment. HMDs can completely isolate the user from the real world. However, the limitation of using HMD is that it is only for individual use, and longer exposure with HMD may cause cyber-sickness Pertaub *et al.* (2002). Other studies used CAVE or large screens to simulate their VR scenes. The details of these apparatus are in Section 2.3.2.

| Author | 3D modelling tool | VR engine | Hardware |
|---|---|---|---|
| North *et al.* (1998) | VRcreator | N/A | Pentium-based PC (100MHz), HMD (Virtual IO) |
| Harris *et al.* (2002) | VRcreator | N/A | HMD (Virtual IO) |
| Pertaub *et al.* (2002) | VRML | Distributed Interactive Virtual Environment V 3.3 (Engine) | Silicon Graphics Onyx twin 196Mhz R10000 processor, HMD (742X320), five button 3D mouse, Polhemus FastTRACK(Head tracker) |
| James *et al.* (2003) | VRML | Distributed Interactive Virtual Environment V 3.3 (Engine) | Four-walled immersive stereo projection Cave-like system(reactor), Try |
| Jo *et al.* (2001) | 3D Max | Visual C++6.0, DirectX 7.0a SDK, Intel Computer vision Library | Pentium III, HMD(Proview XL50), Polhemus FastTRACK (Head tracker) |
| Lee *et al.* (2002) | 3D Max | Visual C++6.0, DirectX 7.0a SDK, Intel Computer vision Library | Pentium III Panorama Camera (Sony MVC-CD1000), Digital camcorder (Sony DCR-VX2000), Head-tracker and HMD |
| Roy *et al.* (2003) | 3D studio MAX 4 (Modelling) | Virtools Dev 2.0 (Engine) | Large monitor screen |
| Klinger *et al.* (2005) | 3D studio MAX 4 (Modelling) | Virtools Dev 2.0 (Engine) | Large monitor screen |
| Anderson *et al.* (2003)Anderson *et al.* (2005) | N/A | N/A | HMD, Handle hand puck |
| Cornwell *et al.* (2006) | N/A | N/A | HMD |
| Grillon *et al.* (2006) | N/A | VHD++ Trolltech13 QT library | HMD (Kaiser Proview XL50), earphone, bio-feedback and CAVE |
| Brundage *et al.* (2006) | Scentpalette | N/A | Dell P-IV with nVidia Fx5200, VFX-3D (HMD) |
| Muhlberger *et al.* (2008) | N/A | N/A | Large monitor screen |

Table 2.3: Various VR Technologies Used in VRET for Social Phobia

### 2.4.3 Virtual Social Scenarios

A variety of virtual social situations have been developed in order to produce an anxiety-provoking atmosphere. By Holt's hierarchical classification of social phobia (Holt *et al.*, 1992), the virtual social situations were categorised into four domains: performance (*speaking in public*), informal speaking (*establishing contacts, small talk*), observation by others (*protecting one's interests, view points, being respected*), and assertiveness (*acting while being under scrutiny*). Eight out of a total of 13 studies focused on performance anxiety (*e.g. a public-speaking situation*), and the remaining five studies created other types of social anxiety (*e.g. a wine-bar, an underground train, a coffee shop and a lift*). Two studies (Roy *et al.*, 2003 and Klinger *et al.*, 2005) considered generalised social phobia (*anxiety in almost all social situations*), while the others focused on a specific subtype of social phobia (*limited to the fear of a single or small number of situations*). Table 2.4 summarises the previous study by the researchers, including the subtype of social anxiety, virtual scene, target fear, and VR stimulus.

| Author | Research Group | Subtype of Social Anxiety | Virtual Scene | Target Fear | VR Stimulus |
|---|---|---|---|---|---|
| North *et al.* (1998) | Atlanta Univ.,USA | Performance | Auditorium | Public Speaking | Number of Avatars/Audio response |
| Harris *et al.* (2002) | | | | | |
| Pertaub *et al.* (2002) | UCL, UK | Performance | Seminar room | Public speaking | Positive and Negative attitudes of Avatar |
| James *et al.* (2003) | | Informal speaking Observation | Wine-bar/Train | Establishing contacts, Acting while being under scrutiny | Natural/Socially intense situation |
| Jo *et al.* (2001) | Hanyang Univ., Korea | Performance | Class room | Public speaking | - |
| Lee *et al.* (2002) | | | | | |
| Roy *et al.* (2003) | GREYC, France | Performance Informal speaking, Observation Assertiveness | Seminar room, Kitchen, Coffee shop, Shoe store | Presentation, Small talk, Acting while being under scrutiny, Walking around | Tasks (presentation, ordering coffee, small talk)/Attention |
| Klinger *et al.* (2005) | | | | | |
| Anderson *et al.* (2003) | Georgia Univ., US | Performance Assertiveness | Seminar room | Public speaking | Task (presentation)/Attention |
| Cornwell *et al.* (2006) | Maryland, US | Performance | Seminar room | Public speaking | Task/Number of Avatars |
| Grillon *et al.* (2006) | EPFL, Switzerland | Performance Assertiveness | Individual Room Auditorium | Job interview, Public speaking | Task/Attitudes of Avatar |
| Brundage *et al.* (2006) | George Washington Univ., US | Performance Assertiveness | Individual Room | Job interview | Challenging/ Supportive Avatars |
| Muhlberger *et al.* (2008) | German | Observation | Lift | Acting while being under scrutiny | Happy/Unhappy Faces of Avatars |

Table 2.4: Summary of Relevant Case Studies

The first study in VRET for social phobia was conducted by North's research team in 1998. They contrived a virtual auditorium that comprised three sections of chairs and accommodated an audience of up to 100. The VR environment allowed the experimenter to trigger the numbers in the audience as a stimulus for provoking anxiety. Several audio clips were also employed to respond to the presenters or to create a variety of situations for them to experience, for example laughing, making comments, encouraging the speaker to speak louder or more clearly, and clapping hands at the end of or during the session. The limitation of this virtual environment appeared to be that most of the feedback from the audience was auditory, with limited appearance and actions of the individuals in the virtual audiences.

Pertaub *et al.* (2002) constructed a virtual seminar room that was inhabited with eight virtual audience members seated in a semicircle facing the participants (Figure 2.11). These avatars displayed random autonomous behaviours, such as twitches, blinks, and nods, designed to encourage the illusion of life. The avatars were able to display six primary facial expressions, together with yawns and sleeping faces. Avatars could also stand up, clap, and walk out of the seminar room, cutting across the speaker's line of sight. The key technique of this system was to simulate each avatar's gaze to enable eye-contact with the participants and for the avatars to move their heads to follow the participants in real-time.

Figure 2.11: VRET Reported from Pertaub et al. (2000)

Later on the same research team - James *et al.* (2003) - designed a London tube and a wine-bar scenario using a VE to provoke social anxiety (Figure 2.12). The London tube scene comprised virtual passengers sitting on the seat in the virtual train car, and some of them standing near the door on the tube train. The wine-bar scene contained seven avatars (four female and three male) within a bar environment. The researcher investigated subjective measurements of social anxiety both in a socially neutral situation (travelling on the London underground) and a socially intense experience (talking with people in a wine bar). Despite the lack of realism, social anxiety was provoked in a socially neutral setting.

Figure 2.12: VRET Reported from James et al. (2003)

Roy *et al.* (2003) and Klinger *et al.* (2005) used the technique of 3D-sprites to represent characters in the virtual environments (Figure 2.13). The characters were designed with simple plain surfaces that were used to simulate single objects with video textures. Situations for four different subtypes of social anxiety (performance anxiety, informal speaking anxiety, observation anxiety, and assertiveness anxiety) were developed for the target of generalised social phobia care. For the performance-anxiety situation, they designed a virtual meeting room with seven audience members who were already sitting around a table and looking at the presenter. In addition, they created an apartment environment for informal speaking anxiety. The VR environment comprised a table set for dinner, a lounge, a kitchen, and decorative objects such as lamps, shelves, and pictures. Four human avatars were placed around the table, and started speaking in an informal manner to the participants. Moreover, a coffee shop scenario was created for the observation anxiety situation. There were many people in this scenario, sitting on benches or standing up, who were smiling or had unhappy faces. For the assertiveness anxiety situation, they created a building with three floors, a street, and a shop. Two people were in the lift. Three people downstairs blocked the exit of the hall. In the shoe store, a director and two assistants tried repeatedly to sell shoes to the participants. All situations successfully provoked anxiety, but the author concluded that the assertiveness situation provoked lower levels of anxiety than the other situations.


Figure 2.13: VRET Reported from Roy et al. (2003)

Grillon *et al.* (2006) developed several virtual situations (e.g. a cafeteria, an auditorium, and an office) (Figure 2.14). The office environment consisted of a work place where a meeting with several people was organised. Up to seven virtual humans were placed around a table in order to face the subject. They were all animated with dedicated animations according to their gender and style: women fixed their hair or checked their nails, a well-dressed man sat quietly and a younger one took a more relaxed posture by crossing his legs and arms. A sound atmosphere recorded in similar real conditions supported the feeling of immersion (e.g. a person clearing their throat, chairs creaking, and distant street noises). The VR situation of this study seems the most realistic VR environment compared with previous studies.

Figure 2.14: VRET Reported from Grillon et al. (2006)

Another VR platform of VRET for social phobia was proposed by Lee *et al.* (2002). The VR environment was displayed using image-based rendering of a real place (Figure 2.15). As many characters as requested could be added to the scene by adding video impostors to the assembly, thus providing live and expressive figures of people in various attitudes. While the system offered various technological improvements to make the simulation more realistic and more interactive, no clinical experiment was conducted.

### 2.4.4 The Impact of Avatars in the VRET for Social Phobia

Across all the relevant studies, virtual avatars have been seen to be a key element in the VRET for social phobia. Nass and Reeves (1996) assumed that people have a natural tendency to treat a virtual avatar as a social actor rather than a mere image, thus it is likely that the computer-generated avatar evokes a similar response. There are several evidences for the role of virtual avatar in VRET for social phobia.

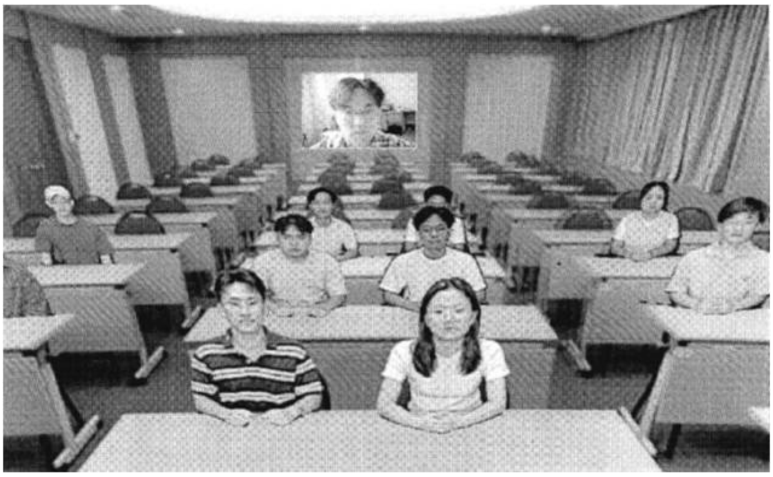


Figure 2.15: VRET Reported from Lee et al. (2002)

Pertaub *et al.* (2002) studied the extent to which fear of public speaking was induced by the virtual audience. The study concluded that participants responded to virtual seminar audiences much as they would respond to real audiences; the participants felt more at ease with a positive group of listeners and experienced considerable discomfort with an unpleasant, unforgiving audience. With the animated audience scenarios and with the negative audience scenario in particular, there was sufficient co-presence to elicit strong affect in the speakers. Later on, James *et al.* (2003) immersed ten non-phobics in various virtual social environments and found an increase in anxiety when users had to interact with virtual avatars who appeared disinterested in the presence of the participants. Even in this unrealistic condition, participants reported significant increases in anxiety and heart rate. Recently Muhlberger *et al.* (2008) studied visual attention during virtual social situations. Twenty-six participants were exposed to virtual avatars with different facial expressions (happy or angry) in a free-viewing virtual elevator situation. Participants' eye movements were recorded. The results indicated that participants initially paid more attention to happy than to angry virtual avatars, and participants who expected to give a talk afterwards were especially likely to sustain attention towards the happy virtual persons and to avoid the angry avatars. Correlation analyses revealed that higher social anxiety was positively related to initial avoidance of happy and angry virtual avatars. Thus, higher socially anxious participants appeared to avoid emotional facial expressions. These results confirm the assumption that faces of avatar are particularly meaningful for socially anxious people.

### 2.4.5 Measurements in VRET

With the purpose of measuring the anxiety outcomes of VRET, the studies utilised a variety of psychological and physiological instruments. According to the domain of anxiety measures by Feske & Dianne (1995) and Gould *et al.* (1997), all the instruments were classified into five categories: general subjective anxiety, specific subjective anxiety, cognitive, behavioural, and physiological anxiety. The full range of these instruments is presented in Table 2.5.

In the domain of general subjective anxiety, the Beck Depression Inventory (BDI) and the State-Trait Anxiety Inventory (STAI) were frequently used for outcome measures of VRET in social phobia care. Three studies (Klinger *et al.*, 2005;Anderson *et al.*, 2003; Grillon *et al.*, 2006) used the BDI scale to measure the level of a user's anxiety during VRET sessions. STAI was also used by three studies (Harris *et al.*, 2002; Anderson *et al.*, 2003;Cornwell *et al.*, 2006) in order to measure the outcomes of VRET for the fear of public speaking.

| Domain | Measure | No. of Studies |
|---|---|---|
| General subjective anxiety | Beck Depression Inventory (BDI) | 3 |
| | Clinical Global Impression (CGI) | 2 |
| | Hospital Anxiety Depression scale (HAD) | 2 |
| | State-Trait Anxiety Inventory (STAI) | 3 |
| Specific subjective anxiety | Attitude Towards Public Speaking questionnaire (ATPS) | 2 |
| | Fear of Negative Evaluation questionnaires (FNE) | 2 |
| | Liebowitz Social Anxiety Scale (LSAS) | 4 |
| | Personal Report of Communication Apprehension (PRCA) | 1 |
| | Personal Report of Confidence as a Speaker (PRCS) | 4 |
| | Rathus Assertiveness Schedule (RAS) | 2 |
| | Self-Statements during Public Speaking (SSPS) | 3 |
| | Social Interaction Self-Statement Test (SISST) | 1 |
| | Subjective Units of Disturbance (SUD) | 1 |
| Cognitive | Immersion Questionnaire (IQ) | 1 |
| | Presence Questionnaire (PQ) | 1 |
| Behavioural | Eye Blinks (EB) | 2 |
| | Gaze Tracking (GT) | 1 |
| | Shuttering Severity Instrument (SSI) | 1 |
| Physiological | Electrocardiographic (ECG) | 1 |
| | Electromyographic (EMG) | 1 |
| | Heart rate (HR) | 1 |
| | Skin conductance (SC) | 1 |

Table 2.5: Psychological and Physiological Measurements in Included Studies

- ✓ *Beck Depression Inventory(BDI)* is a recognised and widely used psychological scale to measure the intensity, severity, and depth of depression in patients with psychiatric diagnoses. This scale is composed of 21 questions, each designed to assess a specific symptom common among people with depression. Items are scored on a 0-3 scale giving a total range of 0-63. Total scores within the 1-13 range indicate minimal depression, 14-19 mild depression, 20-28 moderate and 29-63 severe depression (Beck & Steer, 1987).

- ✓ *State-Trait Anxiety Inventory (STAI)* was initially conceptualised as a research instrument for the study of anxiety. It is a self-report assessment device which includes separate measures of state and trait anxiety. Results also help distinguish between symptoms of depression and symptoms of anxiety. The STAI consists of two scales containing 20 items each. One scale addresses state anxiety while the other scale addresses trait anxiety. The total score indicates which type of anxiety is prevalent (Spielberger *et al.*, 1970).

For specific anxiety measures, four studies (Roy *et al.*, 2003;Klinger *et al.*, 2005;Grillon *et al.*, 2006;Harris *et al.*, 2002) used the Liebowitz Social Anxiety Scale (LSAS), and another four studies (Pertaub *et al.*, 2002; Harris *et al.*, 2002; Anderson *et al.*, 2003; Anderson *et al.*, 2005) utilised the Personal Report of Confidence as a Speaker (PRCS).

✓ *Liebowitz Social Anxiety Scale (LSAS)* is a clinician-administered, semi-structured interview designed to assess DSM social phobia through the evaluation of fear and avoidance in social situations. Formal interviewer training is not required. The LSAS includes 24 items, 13 describing performance situations and 11 describing social interactional situations. Each item is rated separately for fear and avoidance. The LSAS thus yields four subscales: fear social, avoidance social, fear performance, and avoidance performance (Liebowitz, 1987)).

✓ *Personal Report of Confidence as a Speaker (PRCS)* consists of 104 items designed to assess the subject's fear of public speaking. This version (Gilkinson, 1942) proves to be cumbersome when used as a screening tool. (Paul, 1966) produced a shorter, upgraded form of the PRCS by selecting the 30 most discriminating items from Gilkinson's questionnaire. Paul's version of PRCS asks subjects to base their responses on their most recent experience of speaking in front of an audience. The format of this version is true/false with possible scores ranging from 0 to 30.

✓ *Self-Statements during Public Speaking (SSPS)* is based on the SISST (Hofmann & DiBartolo, 2006) to measure fears during public speaking. The SPSS scale is a ten-item questionnaire consisting of two five-item subscales, the positive self-statement (SSPS-p) and the negative self-statement (SSPS-n).

Furthermore, several physiological assessment tools were employed to identify the participant's avoidance of significant facial features. Eye Blinks (EB) and Gaze Tracking (GT) were used by the study of Grillon *et al.* (2006) and Cornwell *et al.* (2006) used Electrocardiographic (ECG), Electromyographic (EMG), Heart Rate (HR), and Skin Conductance (SC).

Most measures of anxiety have been primarily, and often exclusively, subjective. Although the results of the above-mentioned relevant researches were very impressive, it seems that additional research is still needed to conduct a more thorough investigation by using methods that allow both objective and subjective measurements of anxiety.

### 2.4.6 The Effectiveness of VRET for Social Phobia

Six out of a total of 13 studies conducted a randomised clinical trial to demonstrate the effectiveness of VRET for social phobia. In order to calculate the effect-size of the studies, Hedges' g value was employed Hedges (1981). When the necessary data were available, all effect-sizes were calculated directly using the following formula (Equation 2.1):

$$g = \overline{X_T} - \frac{\overline{X_c}}{S_p} \quad (Equation 2.1)$$

, where

g is effect-size,

$\overline{X_T}$ is the mean of the treatment group,

$\overline{X_c}$ is the mean of the comparison group,

$S_p$ is the pooled standard deviation.

If these data did not appear in candidate studies, g was estimated using conversion equations for significance tests (e.g. t, F value; Rosemthal, 1991). The selected studies with multiple measurement results were categorised as Table 2.5 above and combined within each anxiety domain. When there were used multiple measurements per domain, primary outcome measures were only selected to calculate the size of effect. All work was completed with the assistance of computer software (SPSS 1.5). The computed effect sizes could then be interpreted with Cohen's standard of small (0.3), medium (0.5), and large (0.8) effects (Cohen, 1988). The following Table 2.6 shows the details of the effect-size of indicated studies.

Six out of 13 studies conducted a controlled trial to test the effectiveness of virtual reality exposure treatment. Two studies compared VR group to no treatment/waitlist, two studies compared baseline scores to post-treatment or follow-up, and two studies took a randomised control trial to evaluate the effectiveness difference between a VR treatment group and a CBGT group (Table 2.6). Hedges' effect size was calculated in each study using a random effect analysis. Most studies showed positive effectiveness in the VR treatment, although it

| Author | Target Fear | Instruments | No. of Subjects | Clinical Trial | Effect-size |
|---|---|---|---|---|---|
| North *et al.* (1998) | FOPS | ATPS, SUD | N=16 (VR group/Control Group) | Pre/Post-treatment | Negligible (0.09) |
| Harris *et al.* (2002) | FOPS | PRCS, STAI, LSAS, HR, SUD | N=14 (VR group and Wait-list) | Pre/Post-treatment | Large (0.98) |
| Anderson *et al.* (2005) | FOPS | PRCS, SSPS, PRCA, CGI | N=10 | Pre/post-treatment and 3-month follow-up | Large (1.35) |
| Grillon *et al.* (2006) | SP | LSAS, SISST, BDI GT, EB | N=10 | Pre/mid/post treatment | - |
| Roy *et al.* (2003) | SP | LSAS, HAD, BDI, RAS | N=10 | VRT vs. CBGT | Medium (0.55) |
| Klinger *et al.* (2005) | SP | BDI, LSAS, RAS, HAD | N=36 | VRT vs. CBGT | Small (0.36) |

Table 2.6: Effect-size of Each Study

was difficult to directly compare all studies due to the different measures in fear of social situations and less information about results. Remarkably, Harris's and Anderson's studies showed large effect sizes (Hedges' g: Harris 0.98 and Anderson 1.35), and others showed negligible to medium effect sizes.

*Pre/Post Treatment for VRET*

In the first study for the fear of public speaking (North *et al.*, 1998), 16 subjects were recruited and divided into two groups: VR treatment group (n=8) and wait-list group (n=8). They were treated with VRET that consisted of five weekly sessions lasting 10 to 15 min. For the results, mean of ATPS and SUD pre and post treatment scores of VRT and comparison group subjects were calculated. There was a significant difference between the pre and post test scores of the VR group on both SUD ($p < 0.01$) and ATPS ($p < 0.01$) scales. They indicated that the virtual reality treatment significantly reduced both anxiety symptoms (SUD and ATPS) and the fear to face the phobic situation in the real world.

In 2002, Harris et al. recruited 16 volunteers. All participants were randomly assigned either to the VRET group (n=10) or to a Wait-list (n=6), however two people withdrew from the VRET group. Results on self-report and physiological measures appeared to indicate that virtual reality treatment sessions were effective in reducing public speaking anxiety. Participants in the wait-list group showed significant pre and post testing differences on ATPS only; however, the VRT group showed greater improvements on the other self-report measures and on physiological measures than the wait-list group. From our calculations (Hedges' g), the effect size was large at PRCS (1.82), LSAS (0.86), STAI (0.78), and 0.98 in the average of total measures.

Moreover, Anderson *et al.* (2005) studied a clinical trial to examine a cognitive behavioural treatment for public-speaking anxiety that utilised virtual reality exposure therapy. Ten participants were allocated who met criteria for social phobia. They received individual treatment for eight sessions according to a treatment manual. Treatment consisted of four sessions of anxiety management training followed by four sessions of VRET. To measure the level of anxiety pre and post treatment, the scores of PRCS, SSPS, and PRCA were calculated. The result showed that scores on all measures improved significantly from pre to post treatment and these gains were maintained at follow-up. Participants significantly reduced the fear of public speaking after VRET and were satisfied with the treatment. The effect size (Hedges' g) for all measures was large at post-treatment (1.35) and at the three-month follow-up (0.98).

Recently, Grillon *et al.* (2006) conducted eight VRT sessions over eight social phobic subjects. She used LSAS, SISST, BDI, and Gaze Tracker to evaluate the efficiency of VRET. The results showed a general improvement in the various questionnaires, and visual contact avoidance decreased after VR treatment sessions. Due to lack of data and information the effect size could not be calculated.

*VRET against CBGT*

Two studies (Roy *et al.*, 2003 and Klinger *et al.*, 2005) compared a VRET with a cognitive behaviour group therapy. In 2003, Roy developed a VR-based treatment for social phobia and successfully completed a pilot study with ten participants. In 2005, Klinger and Roy studied a clinical trial with large samples to compare VR therapy and CBT for social phobia. Thirty-six participants were diagnosed with social phobia and assigned either to VRT (n=18) or a CBGT (n=18). The virtual environments used in the treatment recreated four situations dealing with social anxiety. With the help of the therapist, the patient learned adapted cognitions and behaviours in order to reduce anxiety in the corresponding real situation. Both treatments lasted 12 weeks, and sessions were delivered according to a treatment manual. Results showed that both VR treatment and CBGT were statistically and clinically significant and showed improvements on the LSAS. The effect-sizes, comparing the efficacy of VRT to the control traditional group CBT, revealed that the differences between the two treatments were minimal.

### 2.4.7 Discussion

The systematic review was conducted to identify previous work using VRET for social phobia, as well as any evidence of effectiveness of VRET in comparison to traditional exposure therapies for social phobia. The first study of VRET for social phobia was started by North et al. in 1998. Further researchers have explored this area. No significant complications have been revealed, and it is obvious that the studies have made a great contribution towards laying the foundations of VRET for social phobia.

Most of the selected studies have targeted the fear of public speaking in various social situations. North *et al.* (1998) contrived a VR seminar situation that allowed the investigator to choose the size of a virtual audience and to trigger the virtual audience's behavioural or aural reactions as a stimulus for inducing anxiety. The study verified the possibility and effectiveness of using a VE to provoke anxiety. It was useful to investigate the effectiveness of VRET within one social situation. However, evaluation in more complex social situations is needed in further studies.

Relevant studies have noticed the importance of the virtual avatar as an essential component in provoking social anxiety in VEs. These studies have supposed that individuals can react emotionally to virtual avatars, even if they are unrealistic representations of real humans. However, there is too little evidence to clarify the role of virtual humans in VRET. Only Pertaub *et al.* (2002) have attempted to study the relationship between an individual's anxiety levels and the attitude of virtual humans. Thus, more research is required to understand the functions of virtual humans in VRET for social phobia and their influence on the levels of anxiety felt.

As the studies outlined in this review show, VRET is a promising modality as effective as exposure in treating fear of social interaction. To measure the effectiveness of the treatment, most studies have primarily used self-report questionnaires or often exclusively subjective measurements. While the results of the relevant researches were very impressive, additional research is still required to conduct a more thorough investigation by using methods that allow both objective and subjective measurements of anxiety.

To date, four studies have been published that did not compare VRET with another form of treatment, while two published studies compared VRET for social phobia with traditional cognitive behaviour therapy. While the studies demonstrated the potential outcomes of VRET for social phobia, at least to some degree, VRET still needs to be compared to conventional clinical therapies with appropriate sample sizes and methodologies. In addition, VR has not yet been shown to be superior to other forms of computer-assisted psychotherapy.

## 2.5 Summary

This chapter explored the fundamental knowledge of social phobia, including a definition and prevalence, characteristics, and conventional treatments. This thesis has established that social phobia is one of the commonest psychological disorders in our society. In order to understand the characteristics of social phobia, the cognitional, behavioural, and physiological features of social phobia were explored. From a cognitive aspect, social phobia involves excessive concern about the evaluations made by other people. From a behavioural aspect, behaviours of escape and avoidance are general manifestations in social phobia. From the physiological aspect, social phobics manifest the same somatic symptoms as those observed in other anxiety disorders. The most popular and commonly used clinical treatment for social phobia is Cognitive Behaviour Therapy (CBT), which incorporates exposures to feared situations, cognitive restructuring, and homework assignments for in-vivo exposure.

Recently, a number of studies have demonstrated the feasibility of using virtual reality technology as a therapeutic tool for social phobia care. This virtual-reality-based therapy has distinct benefits that overcome some of the difficulties inherent in the conventional in-vivo or imaginal technique in CBT. The use of virtual reality in psychotherapy provides the capacity for real-time monitoring of a patient's symptoms with systematically controllable stimuli in a high degree of safety. The exposure process normally takes place in a private room, which means that patients do not have to be exposed to unpredictable and dangerous situations and can be treated in a safe and controlled environment.

A systematic overview of all relevant studies in VRET for social phobia was conducted, and an impartial summary of their findings presented. The previous studies demonstrated the feasibility of VRET in social phobia care, and its underlying mechanisms. Despite such promising clinical uses, the exact effectiveness of this form of therapy for social phobia is still unclear, thus various controversial issues remain.

CHAPTER 3

# Research Methodology

Methodology has been defined as "*a theory and analysis of how research should proceed*" (Bangay & Preston, 1987) or as "*the study - the description, the explanation, and the justification - of methods, and not the methods themselves*" (Kaplan, 1964). Hence, the aim of this chapter is to describe the methodology and to understand the research process itself, including the scope of investigation, experiment design, materials, measurements and their analysis process.

## 3.1 The Scope of Investigation

As Chapter 2 noted, a number of studies have been carried out to demonstrate the feasibility and efficacy of the virtual reality system within a therapeutic treatment for social phobia. However, almost all the relevant studies have neglected to understand the impact of perceptual presence factors in anxiety-provoking VRET for social phobia. The aim of this research is to contribute to the existing theoretical foundation for the development of virtual-reality-based interventions for social anxiety care by understanding the impact of VR apparatus and pictorial realism in an anxiety-stimulating virtual environment. This is done by evaluating individuals' emotional experiences and behavioural tendencies in different conditions of virtual environment. In this section, the research aims are reiterated to define the scope of investigation and to establish a research questions.

The research aims are:

- ✓ *To review the evidence of different treatment for social phobia.*
- ✓ *To identify design issues in the development of virtual reality exposure therapy for social phobia.*
- ✓ *To develop a model of anxiety-provoking virtual social simulations.*
- ✓ *To identify the target population's perspectives on the model of virtual social simulations.*
- ✓ *To identify the relationship between virtual realism and human anxiety in the virtual social simulation.*
- ✓ *To identify the influence of perceptual virtual apparatus in the virtual social simulation and its correlation to human anxiety.*

To achieve these research aims, the following research questions were formulated to define the scope of investigation for this research.

### 3.1.1 User Evaluation

The fundamental requirement of the virtual social simulation for therapeutic purposes is to generate the perceptual realism of the virtual environment in order to elicit fear or anxiety to an extent that is similar to a real-life experience. Even if the virtual social simulation is well designed, user evaluation is an essential process in the development of a system. In order to address the issues of system testing, the capacity to evoke anxiety, and reality testing, the following research questions were formulated:

- ✓ *How well does the virtual social simulation fit the needs of the psychological approach and target population?*
- ✓ *How well does the virtual social simulation evoke the sense of presence?*
- ✓ *Is the virtual social simulation capable of inducing anxiety?*

These considerations were intended to identify the usability of the system and to recognise unanticipated consequences that have not yet appeared in the literature. These questions are addressed by the preliminary study presented in Chapter 4.

### 3.1.2 Anxiety and the Realism of Virtual Humans

In conventional treatment of social anxiety disorder, one goal of the therapist is to desensitise the patient's anxiety or fear through a gradual exposure to the anxiety-producing stimuli which can be represented by human interaction in a social situation. Therefore, the VR treatment has to allow clinical therapists to control over the level of interaction in a gradual manner. Most of the relevant studies mentioned in Chapter 2 used the controlled responses of avatar crowds (North *et al.*, 1998) or the reactions of an avatar (Pertaub *et al.*, 2002) to activate anxiety in a gradual manner. However, there is still uncertainty about how best to understand the impact of the avatar's realism as well as the way to determine a patient's anxiety level in the virtual social simulation. Hence, the interest of this study is how an individual's anxiety experience varies in accordance with the different appearances of avatars in the virtual social simulation, and how much visual and behavioural realism of the virtual human is required to provide a suitable virtual therapeutic environment for social anxiety care. Bearing this in mind, research questions were formulated as follows:

- ✓ *How does the individual's anxiety vary in relation to different graphic fidelity of avatars in a social-anxiety-stimulating virtual social simulation?*
- ✓ *What is the level of graphic detail of avatar required to mimic the anxiety felt by individuals attending a real interview?*

These questions are addressed in Chapter 5 with a study comparing individuals' anxiety occurrence in a real-life situation with VR simulations using three different levels of graphic detail of virtual humans.

### 3.1.3 Anxiety and Immersive Levels of VR Environments

The concept of immersion is a physical configuration of the user interfaces in a VR system, which has a strong correlation to the sense of presence (Slater & Wilbur, 1997). Nevertheless, a few studies related to VRET have argued that the relationship between immersion and sense of presence may be erroneous in VR treatment because of the nature of potential users (Krijn *et al.*, 2004; Bullinger & Riva, 2005). Based on their hypotheses, this study supposed that anxiety may relate non-linearly to immersive levels in VRET for social phobia, although no actual evidence for this exists. Hence, research questions were:

- ✓ *How does the individual's anxiety vary between different immersive levels of VR environment for a social-anxiety-stimulating virtual simulation?*
- ✓ *What is the relationship between the levels of anxiety and the levels of immersive VR displays?*

To address these questions, the severity of anxiety produced by three different types of immersive VR environment - fully, semi, and non-immersive - was compared. This experimental study is explained in Chapter 6.

## 3.2 The Design of Exploratory Studies

The main paradigm of this research was based on the theory of Stimulus-Organism-Reaction-Consequences (Blake *et al.*, 2000). Subjects were exposed to an anxiety-provoking situation as a stimulus threshold which was artificially generated by virtual reality technology. When the subject developed a mental representation of the virtual stimuli as their own environment, they may have felt anxiety and have attempted to escape from the source of danger by subtle avoidance plan or safety behaviours. The evaluation of such reactions, in order to identify the correlation of these reactions with various conditions of virtual stimuli, was the key element in this research. Participants' cognitive and behavioural responses to different conditions of virtual environment were observed and evaluated using the combination of an observational and an experimental study (figure 3.1).

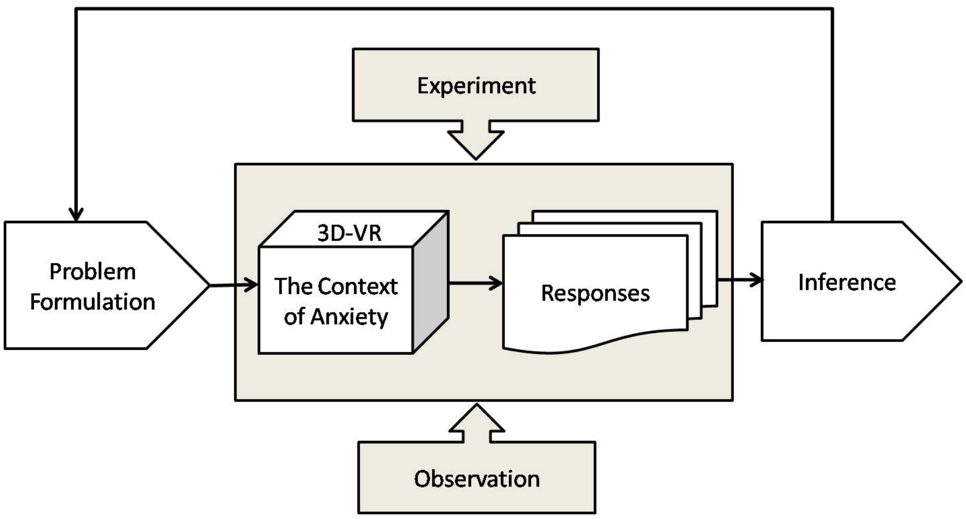



Figure 3.1: Research Framework for Obtaining Individuals' Responses

This mixed research method enabled a full understanding of individuals' behaviour tendencies and their subjective experiences of the anxiety-stimulating virtual social simulations to be attained. In order to address the research questions that were mentioned in section 3.1, one preliminary study and two different experimental studies were conducted, with a common theme: the relationship between social anxiety and the perceptual presence factors of virtual social simulation. However, each study was conducted using different research objectives.

### 3.2.1 Defining Dependant and Independent Variables

The purpose of this research was to observe how people respond to different conditions of virtual reality environment. The individual's responses, particularly the level of anxiety, were chosen as a dependant variable. This was measured using behavioural, physiological, and verbal measurements. The measured data were reproduced to comparable variables for quantitative analysis. The independent variables were manipulated to create different conditions for comparison, for example the graphical fidelity of virtual avatar or immersive levels of VR environments. The details of variables will be defined in Chapters 4, 5 and 6.

### 3.2.2 Experiment Design

This research mainly used a *Within Subjects Model* (or Repeated Measures Design) to directly compare the anxiety levels of individual subjects in one condition to their anxiety responses in another. Due to its repeated observations of a respondent, error variance which is related to individual differences can be reduced (Gregory & Bridget, 2007). However, the *Within Subjects Design* has a typical weakness which can be referred to as "*sequence effects*" (Gregory & Bridget, 2007). In the repeated measures design, a participant is allocated into two or more different treatments; thus, the responses in one condition may affect those in another condition. Therefore, in order to eliminate any practice or sequence effects, the treatments were counterbalanced by test orders and conditions. For example, half of the subjects in a group worked with condition A first and then with condition B. The other half worked with condition B first and then with condition A (Figure 3.2). In addition, multiple observations were used to evaluate the sequence effects over an experiment. The study compared validated self-report anxiety scores before and after treatment. From this control procedure, participants' responses could be equivalently collected with less carryover influences, and the procedure also had the advantage of reducing experiment time and sample size. The following two figures illustrate the details of experimental design in Chapters 5 and 6 (Figures 3.2 and 3.3).

| Group Name | Session Order | |
|---|---|---|
| | First Test | Second Test |
| G1 | A | C |
| G2 | B | A |
| G3 | D | A |
| G4 | C | B |
| G5 | C | D |
| G6 | D | B |

Figure 3.2: The Counterbalanced Treatment by Orders and Conditions for the First Study in Chapter 5

| Group Name | Session Order | |
|---|---|---|
| | First Test | Second Test |
| G1 | A | D |
| G2 | B | C |
| G3 | D | B |
| G4 | C | A |

Figure 3.3: The Counterbalanced Treatment by Orders and Conditions for the Second Study in Chapter 6

## 3.3 The Development of the Virtual Social Simulation

A job-interview scenario was chosen to be developed in order to provoke anxiety. The fear of job interviews is one of the commonest manifestations of social anxiety, which belongs to the domain of assertiveness or performance anxiety in the subtype of social phobia (Holt *et al.*, 1992b). It is characterised by an intense fear of embarrassment in a job-interview situation, often accompanied by significant social disabilities (Rynes *et al.*, 1991). Unlike other social situations, the job interview is highly evaluative and the competitive nature of the situation can evoke a feeling of anxiety (Heimberg *et al.*, 1986). In addition, the job interview is not within the applicant's control, and this lack of control may lead to an increase in anxiety (Jones & Pinkney, 1989).

In terms of the design of the VR simulation, the job-interview situation was simple and easy to be reconstructed as a virtual environment. Other social situations are more complex; for example, the public-speaking scenario requires a large audience and an auditorium. The job-interview situation required only a small number of virtual humans, therefore less time was needed to develop a virtual scene (*e.g. a private office or room and one or two interviewers*). Moreover, due to the job interview being commonly conducted by a one-to-one (or face-to-face) interaction, it seemed a more effective environment to understand the correlation between the individual's experiences and the virtual environment without confounding extraneous variables.

In Chapter 2, several fundamental considerations were identified to develop an anxiety-provoking VR simulation, such as the sense of presence, interactions of a virtual human, stimulus, task, and cyber-sickness. Based on the basic knowledge of human factors in VR, a high graphical fidelity of virtual job-interview scenario was created in collaboration with the Centre of Warwick Careers Service and

Warwick Medical School. The following subsections describe the technical details of the virtual job-interview simulation.

### 3.3.1 A Virtual Office for a Job Interview

A virtual office was designed, imitating a real private room and including chairs, a desk, a whiteboard, a wall-mounted TV, a rubbish bin and so on (Figure 3.4). The objects were created using Autodesk's MAYA (www.autodesk.com), which is a state-of-the-art commercial 3D modelling tool. To compromise between real-time constraints and visual quality, Virtools (www.virtools.com) was used which programmed the virtual office with a built-in script language (BBs). This VR engine allowed developers to integrate various basic and advanced VR components, and to handle the issues of real-time rendering and the high quality of visual scene (Figure 3.5).

Figure 3.4: Virtual Office for the Job Interview

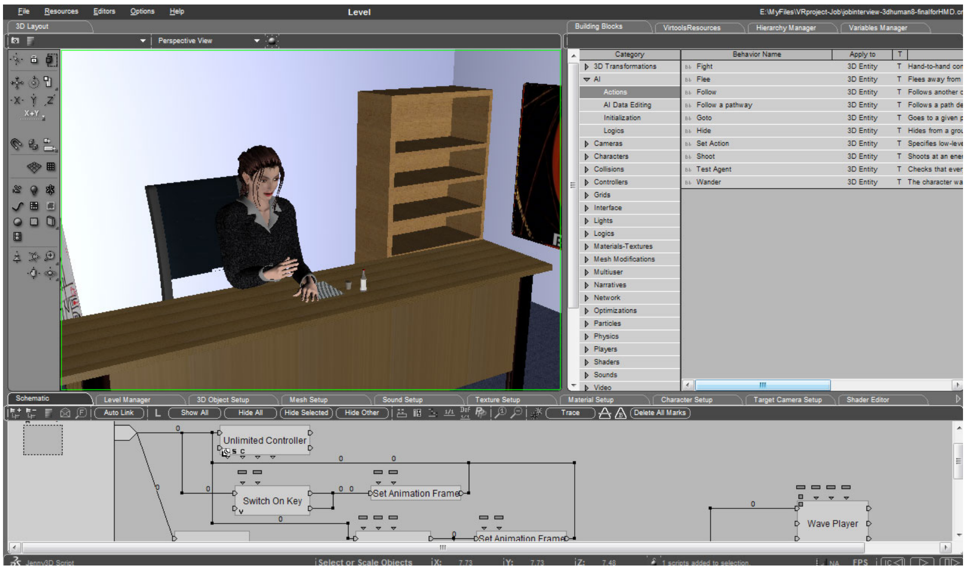



Figure 3.5: Virtual Job Interview Scenario and Virtools SDK

## 3.3.2 Virtual Interviewers

The model for the virtual interviewers was created using Autodesk's MAYA, rendered by Virtools with a built-in behaviour-rendering engine (Shaders 3.0, HLSL and CgFX, DX 9.c and OpenGL 2.0), and programmed by pre-scripted modules for the dynamic animations (Figure 3.6).


Figure 3.6: Virtual Interviewers


Figure 3.7: A Virtual Skin and Skeleton

To simulate lifelike attitudes and gestures, the virtual interviewers were articulated figures that were modelled with multiple hierarchies. A virtual skin was attached to an underlying skeleton that animated the whole body (Figure 3.7). As shown in Figure 3.8, the skeleton consisted of a number of segments (*such as the arms, fingers, and feet*), which were connected to each other by the joints. The animation of the skeleton was performed by four-dimensional matrices associated with the help of inverse kinematics and key-framing. In addition, to obtain a high degree of realism for facial animations, facial deformation techniques were used, such as a blend shape and key frame animation.

The 3D human models were programmed with various animated expressions. For example, they could move lips and blink eyes, and express negative or positive reactions such as smiling, nodding, head-shaking, yawning, turning away, avoiding eye contact, interlocking fingers and looking interested, folding arms and looking disinterested, and so on (Figure 3.9). Furthermore, various sound clips were recorded with the help of the Centre of Warwick Careers Service, for example job-interview questions and phrases such as "*Thank you*", "*Yes*", "*I have heard enough*", "*Okay I am going to go to the next question*", "*Good! That* *sounds interesting*", and so on. These animations and voices were able to be controlled manually by a computer keyboard.

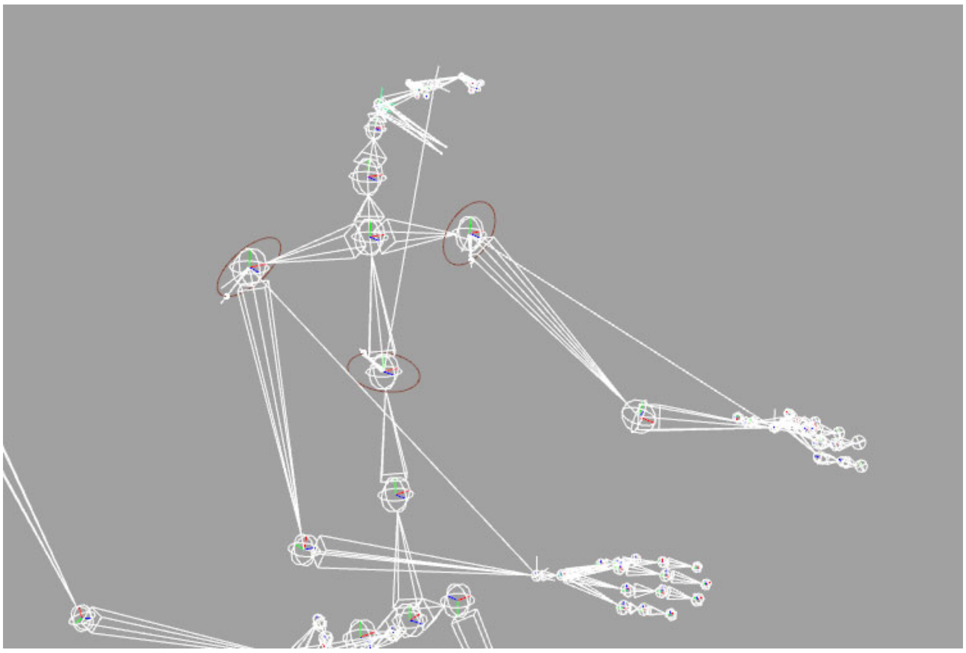


Figure 3.8: Skeleton and Joints

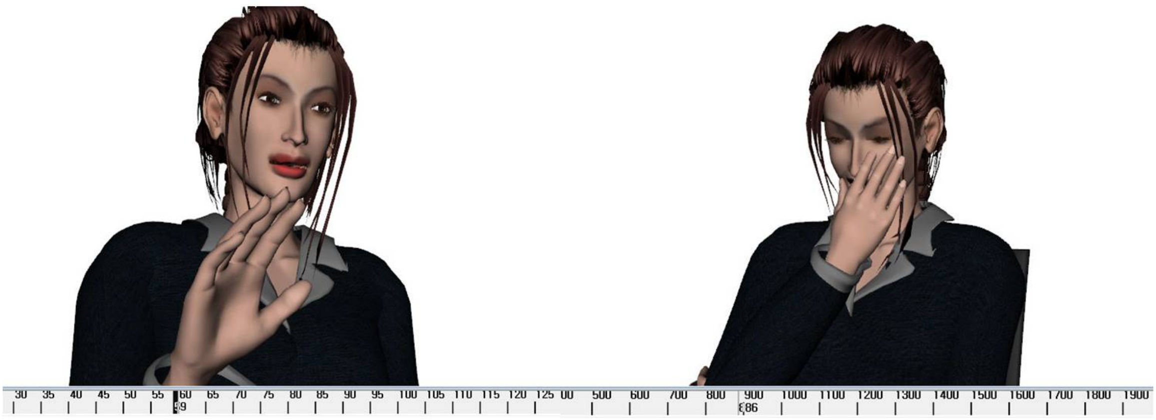


Figure 3.9: Avatar Animations

### 3.3.3 Hardware and System Architectures

The objective of the VR system for this research was not only to deliver a virtual job-interview simulation with high-quality immersive systems that were similar to any professional VR simulation, but also to provide flexible settings so that the investigation could address different research aims. Thus, two different types of VR system were developed.

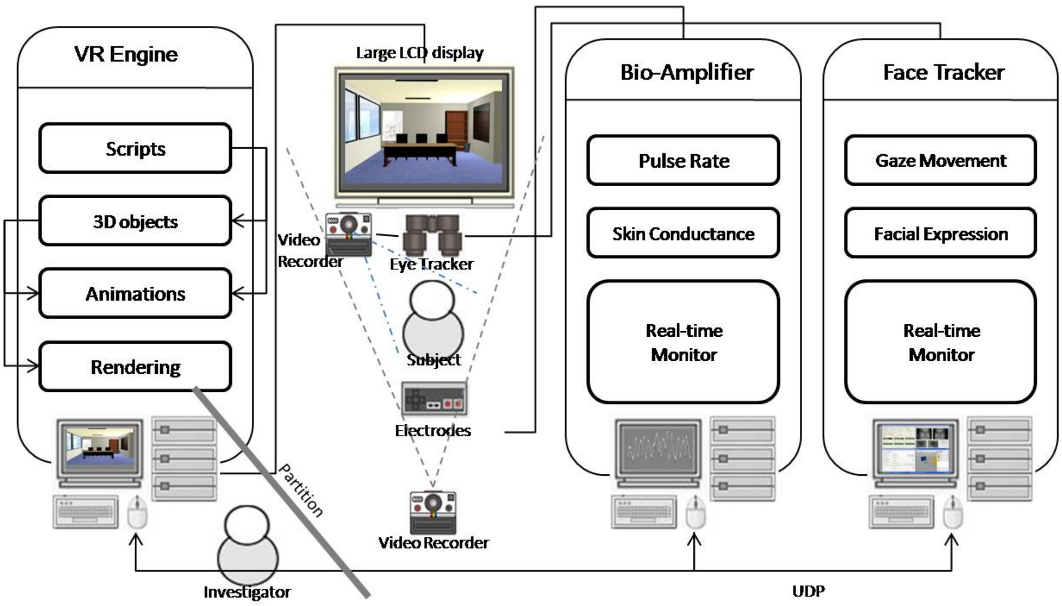



Figure 3.10: Single Projection-based Virtual Reality System

For the first experimental study (Chapter 5), a system was required to obtain information about a participant's physical and physiological responses, including eye movements, behaviour tendencies, pulse rate, and skin conductance response. In order to capture a participant's eye movements over the course of the VR exposure, the simulation was presented by a large LCD screen rather than a Head Mounted Display. The VR system was run by three PCs (Intel Q6600 2.4GhZ core 2 Quad processor and Nvidia Geforce 8800 GTX with 768 MB of RAM) which was synchronised through a User Datagram Protocol (UDP) port to obtain actual time for events, 57-inch LCD Display, Eye tracker (FaceLAB), Webcams (QuickCam S5500), Video Camera, and a Bio-amplifier (Psylab)(Figure 3.10).

In support of the second experimental study, a HMD-based VR system was developed to simulate the virtual job-interview scenario and effectively isolate

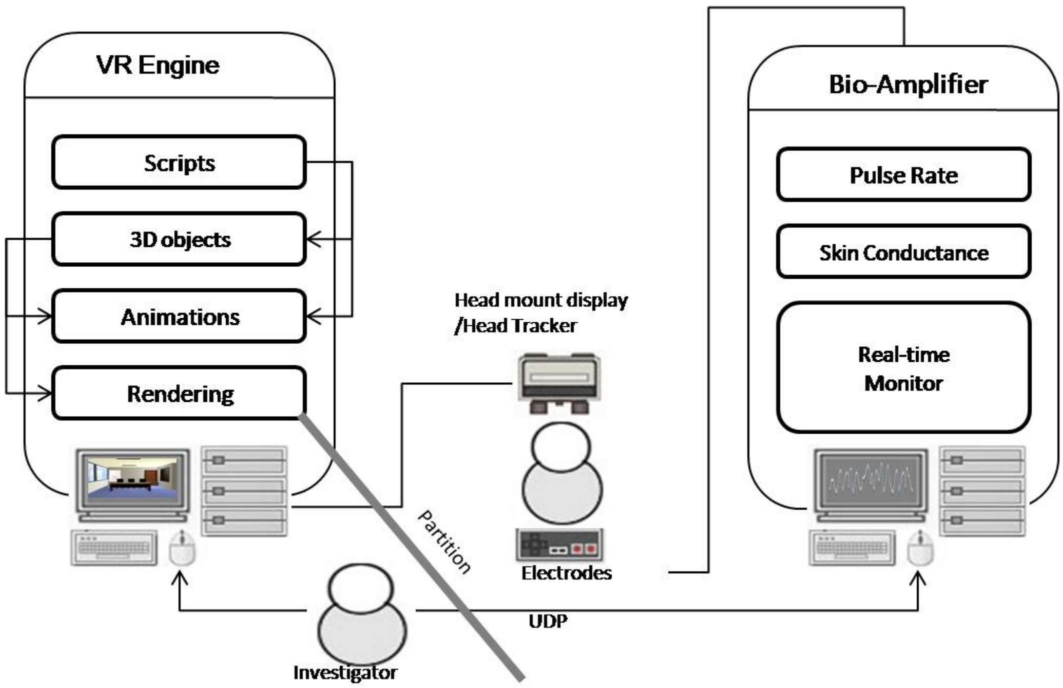



Figure 3.11: HMD-based Virtual Reality System

participants from their surroundings (Figure 3.11). The HMD (NVIS nVisor SX) was encompassed by a head motion tracker (Polhemus 6DOF Motion Tracker) so that the point of view displayed in the monitor changed as the user moved their head. HMD was established to the resolution of 1280X1240X60Hz, and run with Intel Q6600 2.4GhZ core 2 Quad processor and Nvidia Geforce 8800 GTX with 768 MB of RAM. In addition, to measure a participant's psychological responses, the system integrated a bio-amplifier, and the data was presented to a real-time monitoring system. This HMD-based system was able to provide an immersive VR environment and collect physiological data simultaneously.

## 3.4 Measurements of Anxiety

The issues surrounding the measurement of anxiety are complex and technical, because the feeling of anxiety is often associated with multiple channels (for example, subjective experience, facial action, central and peripheral nervous system activation, cognitive or information-processing changes, and behavioural tendencies), and the channels themselves are interrelated in a complex way (Venables, 1984). A number of studies have attempted to find appropriate methods for measuring anxiety. Somatically, anxiety has been measured using the galvanic skin response (Hyman & Gale, 1973), heart rate (Lewis & Drewett, 2006), pupil response (Sturgeon *et al.*, 1989), stomach acidity (Ramesh *et al.*, 2008), and facial musculature (Achaibou *et al.*, 2007). In some cases, cardiovascular parameters (Faraco *et al.*, 2003), such as blood flow, blood pressure, pulse, and cardiac output, as well as electrophysiological apparatus such as the electroencephalogram (Bruder *et al.*, 1997), have been used in studies of anxiety. A non-verbal approach has also been used to measure anxiety by specifying methods for scoring facial expressions from video recordings (Davidson *et al.*, 1990). Moreover, Trower et al. indicated that intonation, speech loudness, and gaze avoidance were also useful to measure anxiety (Trower *et al.*, 1978). Furthermore, verbal methods through self assessments or observer-rated scales have evaluated the degree of anxiety, such as the Social Interaction Anxiety Scale (Heimberg *et al.*, 1992), Fear of Negative Evaluation Scale (Watson & Friend, 1969), Social Avoidance and Distress Scale (Turner *et al.*, 1996), and Liebowitz social anxiety scale (Liebowitz, 1987b). The following table 3.1 summarises a number of potential psycho-physiological measures for states of anxiety and the features of those means of measurement.

From the various lists of measurements that have been used for previous research related to anxiety, it was clear that each measurement has different features, although all had the ability to collect a variety of responses from participants. However, no predominant single measurement exists to distinguish anxiety from other emotional states. This research therefore used multiple measurements, including verbal, behavioural, and physiological approaches. These

| Type | Measures | Features | References |
|---|---|---|---|
| Electrical Activity | EDA, ECG, EEG | Electrical signal running through the human body is recorded from the skin surface using certain electrodes. The electrical signal responses are a sensitive measure for emotional response, and provide highly powerful information on internal psychological processes. Devices for electrical signals provide real-time monitoring charts and are inexpensive. | Andreassi (2007), Hyman & Gale (1973) |
| Cardiovascular Activity | Blood pressure, volume, cardiac output | Korotkoff sounds or pulse pressure is often used to measure blood pressure. The pressure is determined by the variation between systolic and diastolic. Although the measuring device is becoming more handheld and inexpensive, it is not suitable for measuring a short-term period of emotional changes. | Faraco *et al.* (2003),Andreassi (2007) |
| Muscle Activity | Facial EMG | Very thin needle electrodes are inserted into muscle tissue, and measure electronic signal. Due to the painful process, the signal is often measured from the skin surface. This measure is useful for understanding the pattern of emotional reactions, but it has large individual difference (e.g. age and gender). Thus, most physiologists combine measures of autonomic variables with EMG and nervous system activity. | (Achaibou *et al.*, 2007), Andreassi (2007) |
| Behavioural Reaction | Eye movements Startle reflex | The eye movements enable the visual system to acquire information by scanning relevant aspects of the environment. The movements can be measured by eye muscles attached to the outside of each eyeball. However, currently the eye movement is measured using an optical eye-tracker. This device provides information about gaze movement, startle reflex, or pupil response. | Trower *et al.* (1978), Andreassi (2007) |
| Radiotelemetry | Stomach acidity | Using a Heidelberg capsule, the pH of the stomach can be measured by electronic monitoring equipment. Participant needs to swallow the capsule before measuring the level. | Ramesh *et al.* (2008) |
| Verbal Response | Self-rating scales | Self-rating scale is the commonest measure for a participant's emotional state, because anxiety cannot yet be recorded objectively. Accuracy in the measurement of anxiety can be obscured by ordinary sources of error that are always relevant to all questionnaires and rating scales. | Tyrer (1999), Heimberg *et al.* (1992) |

Table 3.1: Psycho-physiological Measures for the State of Anxiety

multiple approaches allowed us to evaluate the participants' anxiety levels and their subjective experiences during the virtual simulation exposure. Table 3.2 illustrates the summary of measurements in each experiment.

| Study | Chapter | Screening Instruments | Behavioural Anxiety | Physiological Anxiety | Verbal Anxiety |
|---|---|---|---|---|---|
| Preliminary | 4 | LSAS* | Eye-Contact /Eye-Blink | - | Semi-Structured Interview |
| First Experiment | 5 | LSAS/BFNE | Eye-Contact /Eye-Blink | PR/SCR§ | MASI† |
| Second Experiment | 6 | LSAS/BFNE‡ | - | PR/SCR | MASI |

*LSAS: Liebowitz Social Anxiety Scale †MASI: Measure of Anxiety Selective Interview ‡BFNE: Brief Fear of Negative Evaluation §PR: Pulse Rate, SCR: Skin Conductance Response

Table 3.2: Summary of Measurements in Each Experiment

### 3.4.1 Physiological Anxiety Measures

The sense of anxiety is often connected to a disturbance of one or more of the somatic functions, for example respiration, heart inaction, vasomotor innervations of the skin of the hand, or glandular activity (Tyrer, 1999). While there are a large number of physiological measures, human electrical activity is one of the most widely used in psycho-physiological measures, including Electrocardiogram (ECG), Electromyogram (EMG), and Galvanic Skin Response (GSR) (Andreassi, 2007). The measure of electrical activity is very useful for recording a short period of time, and is relatively inexpensive to purchase and run with computer-based equipment (Corr, 2006). ECG provides a thoracic interpretation of the electrical activity of the heart over time, captured and externally recorded by skin electrodes. As with skin conductance activity, the ECG and GSR are always used as the dependent measures in human studies of the effects of the awareness of stimuli. These two measures are useful for detecting physiological responses elicited by stimuli presented below the threshold of conscious awareness (Corr, 2006). The measure of skin conductance response from GSR and heart rate from ECG can provide important information that is not obtainable either by a self-rating scale or by other behavioural or physiological methods (Andreassi, 2007). Another possible physiological measure for anxiety is cardiovascular activation, which is often related to emotional responses (Faraco *et al.*, 2003). The patterns of cardiovascular activation (blood pressure or volume) differ between the major categories of emotions (Andreassi, 2007). The device for blood pressure is becoming miniaturised, and is able to obtain accurate blood-pressure measurements. However, it is less appropriate for recording short periods of physiological responses. It requires one minute for the rest period recording, around 20 seconds for measuring, and another one minute for the recovery period (Lang *et al.*, 1994). Moreover, it has a limitation in assuming the level of anxiety from other emotions. Sinha *et al.* (1992). demonstrated that feelings of anxiety, action and joy produced similar blood pressure levels in diastolic readings (Sinha *et al.*, 1992). For these reasons, blood pressure was not selected as an outcome measure.

The research presented in this thesis utilised an electrical activity recording device (Figure 3.12) for heart rate and skin conductance response, in order to obtain data for short periods of time and to enable visual charts to be monitored in real-time. This allowed us to determine the severity of anxiety during the period of the virtual social-simulation exposure.

#### 3.4.1.1 Heart Rate

A number of methods can be used to measure heart rate. The oldest of these is the pulse, which is commonly taken at the wrist and measures the number of beats of the radial artery. In the aspect of measuring anxiety, pulse rate is related

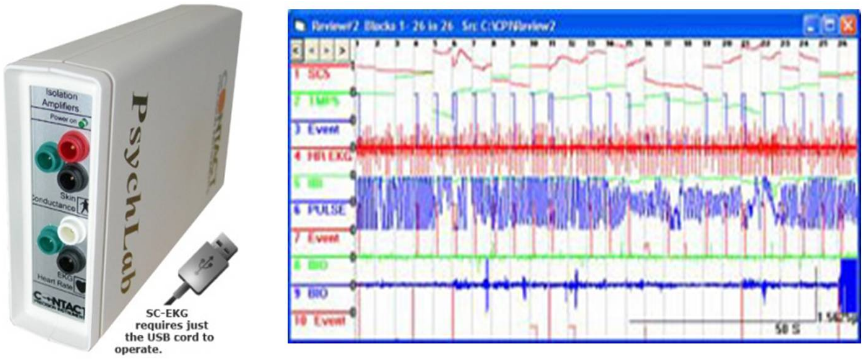



Figure 3.12: A Bio-amplifier for the Measure of HR and SCR

to physical activities rather than anxious mode, because the heart is accompanied by breathing. Universal findings suggest that pulse rate increases during a state of anxiety, although it is difficult to determine the level of anxiety with an actual rate (e.g. does a pulse rate of 90 bpm necessarily indicate that the person feels anxious?) Thus, this research only observed the increment of pulse rate from the normal state (Baseline) to determine the symptoms of anxiety (Equation 3.1):

$$PR - b = \alpha PR - Baseline \quad (Equation 3.1)$$

, where

PR-b is the increase rate of pulse beats per minute,

$\alpha PR$ is the mean of pulse beats per minute,

Baseline is the mean of baseline recordings of pulse beats per minute.

In order to obtain the physiological signal for pulse rate, Contact Precision Instruments' amplifier (www.psychlab.com) was employed. The device was established to acquire the samples in two sec epoch time with the rate of 1000 Hz, buffer byte at 1024Kb, and 50% of graphic speed. The pulse rate was recorded with a pulse transducer attached to an index finger. Customised analysis software (psylab 8.0) was applied to pre-process the data and to remove movement-related artefacts. The average of pulse beats (bpm) was calculated to indicate subjective anxiety level.

#### 3.4.1.2 Skin Conductance Response

Skin Conductance Response (SCR) was used as another anxiety measure in this study. Together with pulse rate, SCR is often used to indicate the symptoms of anxiety. Although individuals with anxiety disorders have generally higher SCR than non-anxious individuals, the use of SCR as a single measurement for anxiety is risky, because an anxious person's sweating may not be connected to the need to control their body temperature, as it would be for a non-anxious person (Tyrer, 1999). Taking the same approach as the measure of pulse rate, this research observed the increment of SCR from baseline recordings to determine the symptoms of anxiety (Equation 3.2). The mean of baseline recordings of SCR was measured together with pulse rate before the participants were exposed to the VR simulation. For the baseline recording a piece of calm music (*Final Fantasy Piano IX: Melodies of Life*) was used.

$$SCR - b = \alpha SCR - Baseline \quad (Equation 3.2)$$

, where

SCR-b is the increase rate of SCR per minute,

$\alpha SCR$ is the mean of skin conductivity startle responses per minute,

Baseline is the mean of baseline recordings of skin conductivity startle responses per minute.

In order to collect the data for the sweat response, a bio-amplifier was utilised (the same device used for measuring heart rate). The activity was recorded with two electrodes attached to the medial phalanges of non-dominated fingers. The amplifier was set up with DC mode, 5 $\mu mhos/\nu$ and 0.5 Hz (subject's baseline return to 0 - 1sec). Among various possible measures for conductance units, the level of conductance changes (SCL) during a given period of time was recorded. The recorded data was manually manipulated to eliminate artefacts, and after that the data was analysed to determine the degree of anxiety.

### 3.4.2 Behavioural Anxiety Measures

As has been noted by most investigators in relation to anxiety studies, escaping and avoiding behaviours were widely used to measure the severity of anxiety (Marks, 1969 and Ohman, 1986). The avoidance of eye contact in particular is one of the major symptoms among anxious individuals (Horley *et al.*, 2003). Horley's study demonstrated that individuals with anxiety were characterised by a lack of gaze fixation, both in number and time, and a noticeably increased length of eye scan-path (Figure 3.13). Moreover, Grillon *et al.* (2006) verified that the degree of anxiety could be measured by the eye-scan velocity which was captured by an eye tracker.

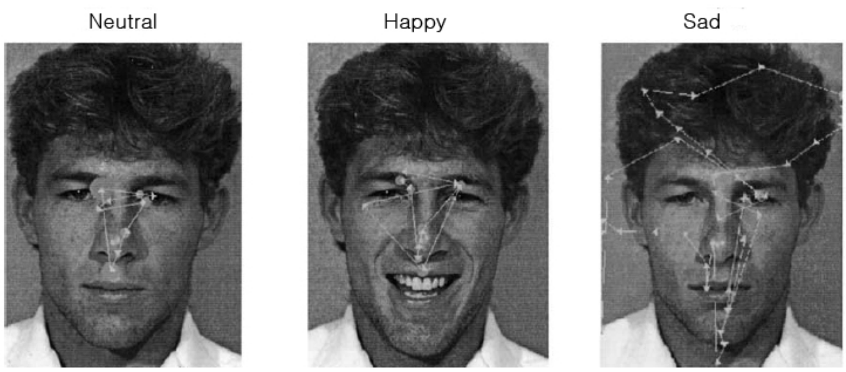



Figure 3.13: Gaze Fixations within Three Emotion States (Horley *et al.*, 2003)

Our research used an eye-tracking device (Facelab 4.0) in order to observe a participant's eye-avoidance behaviour. The eye-tracker was able to obtain the number of gaze fixations at a specific area, with 60 samples taken per second. To compute how many times a participant gazed at the interviewer's face area over the course of the job-interview, the relevant regions of the virtual interviewer's face were established by the function of a Look-Zone (LZ) on the eye-tracker system. The total numbers of gaze samples were rescaled to acquire the rate of gaze fixations at the LZ per second during each job-interview question (RGP), as follows (Equation 3.3):

$$RGP = \left(\frac{\alpha GP}{\beta Time}\right) \quad (Equation 3.3)$$

, where

RGP is the rate of gaze fixations at the LZ per second,

$\alpha GP$ is the observed numbers of gaze point on LZ,

$\beta Time$ is the end of time minus the start of time (Sec.)$\times$60.

The following figure 3.14 shows an example of data acquired by the eye-tracker.

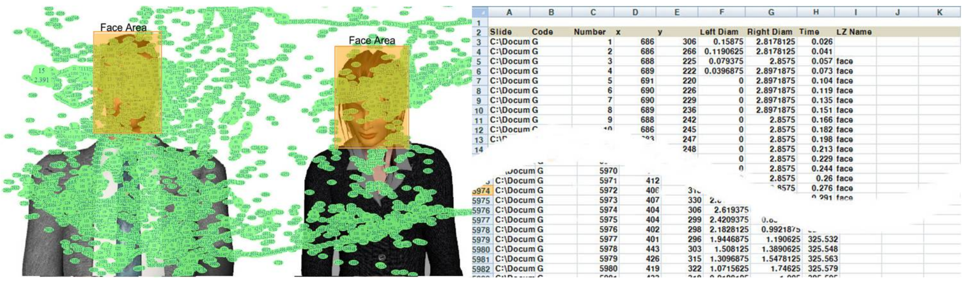



Figure 3.14: An Example of Data Acquired by the Eye-trackerGaze

Furthermore, Harrigan and O'Connell (1996) verified that eye-blink is a good marker to indicate anxiety, as it can increase when nervousness, stress or arousal are experienced. In addition, Gross and Levenson (1993) indicated that the increased rate of eye-blink is associated with increased sympathetic nervous-system activity, and increases in both are related to attempts to suppress anxiety. Thus, we decided to use the frequency of eye-blink as a measure of anxiety. The blink measurement in the eye tracker, which reported the occurrence of blink events, was a binary signal: true or false (Figure 3.15).

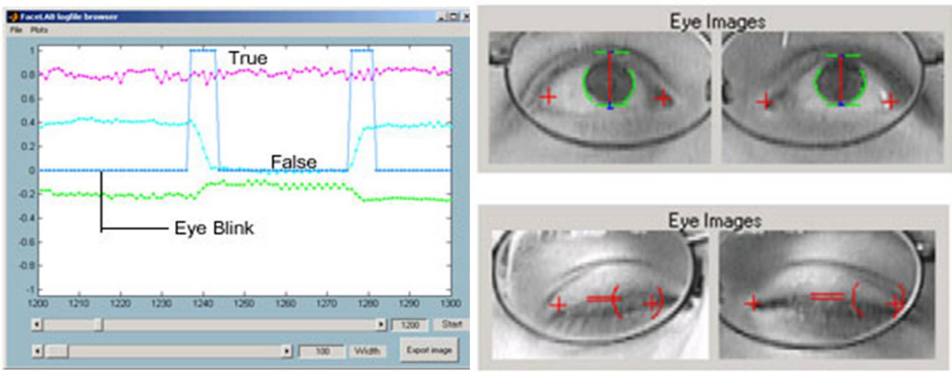



Figure 3.15: From Eye Open to Eye Closed

The eye tracker was set up to capture eye-blink with a maximum duration of 0.35 seconds, and the Percentage of Eye Closure (PERCLOS) threshold was assigned to 0.75 to distinguish between regular short blinks and eye closure. If the time between the actions of eye close and eye open was less than 0.75 seconds, this was regarded as a regular short blink; otherwise, it was classified as eye closure. The rate of blinking (REB) was calculated by the following formula (Equation 3.4):

$$REB = \left(\frac{\alpha EB}{\beta Time}\right) \quad (Equation 3.4)$$

, where

RGB is the rate of eye-blink per second,

$\alpha EB$ is the number of eye blink,

$\beta Time$ is the end of time minus the start of time (Sec.).

The eye-tracker package was installed in front of a screen that presents a virtual simulation. In order to track the participant's face correctly, the camera configuration always kept the participant in view and in focus, and the participant was asked to sit still with their face in view of both cameras before starting the course of VR exposure. Data-acquisition software allowed us to monitor and record real-time eye behaviours including gaze fixation time, scan-path, pupil size, and blink rate. The recorded data were exported to a spreadsheet for further statistical analysis.

### 3.4.3 Verbal Anxiety Measures

Behavioural and physiological measures provide great benefits when interpreting the symptoms of anxiety, but these are often difficult to distinguish from other emotions separate from anxiety. Thus, this research utilised a self-reported questionnaire and semi-structured interview to obtain each participant's subjective experience in terms of the feeling of anxiety during the VR exposure.

#### 3.4.3.1 Screening Instruments

Two validated self-rate scales for measuring the degree of anxiety were used as screening instruments. The instruments were able to indicate appropriate target participants and assign them to equivalent treatment groups. In addition, they were applied to investigate the carryover effects over the experiment study. The screening interments often used in epidemiological studies for indicating the severity of anxiety in community samples. Many of the instruments use quite brief symptom checklists, often offering a general measure of state of anxiety. This research employed two common self-rate scales.

*Brief Fear of Negative Evaluation* (BFNE;Leary, 1983): Leary developed a brief version of the fear of negative evaluation scale that is a widely used measurement for assessing various dimensions of social evaluative anxiety. The scale contains 12 items with responses based on a five-point Likert metric (*1=not at all characteristic of me; 5=extremely characteristic of me*) with scores ranging from 12 to 60. The BFNE was recently validated by Duke *et al.* (2006) and correlated highly to the original scale (r=0.96), the Social Avoidance and Distress Scale (SAD), and the Interaction Anxiousness Scale. Rodebaugh *et al.* (2004) argued that the BFNE is reliable and validated to indicate the severity of anxiety; however, it was restricted to a college student population rather than evaluating social anxiety among clinical populations of anxiety disorder patients (Appendix A.1).

*Liebowitz Social Anxiety Scale* (LSAS; Liebowitz, 1987): LSAS is a self-rate questionnaire which has been widely used in different studies relating to social phobia. LSAS contains 24 items to assess social phobia symptoms in terms of social fear, social avoidance, performance fear, and performance avoidance in 24 social situations. Thirteen of the items ask about performance situations while the remaining 11 situations consider social interaction situations. The respondent's anxiety is rated from one to four using Likert-type scales. According to the total scores between 0 and 144, the severity of anxiety can be measured as moderate social phobia (55-65), marked social phobia (65-80), severe social phobia (80-95) and very severe social phobia (more than 95). The LSAS has been used in most clinical trials for social anxiety disorder (Fresco *et al.*, 2001) and frequently in VRET studies evaluating the efficacy of VR treatment for social phobia (Roy *et al.*, 2003; Anderson *et al.*, 2003; Klinger *et al.*, 2005) (Appendix A.2).

#### 3.4.3.2 Self-Reported Questionnaire

This research used Measure of Anxiety in Selection Interviews (MASI) to measure the degree of anxiety from a verbal approach. The MASI was developed and validated to measure job-interview anxiety in particular (McCarthy & Goffin, 2004). The MASI supports multidimensional measure of interview anxiety across five dimensions: Communication, Appearance, Social, Performance, and Behavioural. Each aspect includes six items respectively (*30 items in total*), and the item can be rated on a five-point response scale (*1=strongly disagree, to 5=strongly agree*). Table 3.3 describes the scope of assessment in each aspect.

| Aspects | Scope of Assessment | Example of Item |
|---|---|---|
| Communication | Anxiety about one's verbal communication | I became so apprehensive in job interviews that I was unable to express my thoughts clearly. |
| Appearance | Anxiety about one's physical appearance | Before a job interview I was so nervous that I spent an excessive amount of time on my appearance. |
| Social | Anxiety about one's social behaviour | I worry about whether job interviewers will like me as a person. |
| Performance | Anxiety about one's interview performance | In job interviews, I got very nervous about whether my performance was good enough. |
| Behavioural | Anxiety about one's behaviour | My heartbeat was faster than usual during job interviews. |

Table 3.3: The Description of Assessment Scope in Each Aspect

For this research, only three distinct anxiety dimensions - Communication, Performance, and Behavioural Anxiety - were selected, because the dimensions of Social and Appearance were less relevant to a VR job-interview setting. Fortunately, each dimension was derived from separate theoretical streams of research, thus each dimension was fragmented (McCarthy & Goffin, 2004). Table 3.4 shows the modified MASI which was used for this research (Appendix A.3).

| **Measure of Anxiety in Selection Interviews (MASI)** |
|---|
| **Communication Anxiety**<br>1. I became so apprehensive in job interviews that I was unable to express my thoughts clearly.<br>2. I got so anxious while taking jobs interviews that I had trouble answering questions that I know.<br>3. During job interviews, I often could not think of a thing to say.<br>4. I felt that my verbal communication skills were weak.<br>5. During job interviews I found it hard to understand what the interviewer was asking me.<br>6. I found it difficult to communicate my personal accomplishments during a job interview.<br><br>**Performance Anxiety**<br>1. In job interviews, I got very nervous about whether my performance was good enough.<br>2. I was overwhelmed by thoughts of doing poorly when I was in job-interview situations.<br>3. I worried that my job-interview performance would be lower than that of other applicants.<br>4. During a job interview, I was so troubled by thoughts of failing that my performance was affected.<br>5. During a job interview, I worried about what would happen if I didn't get the job.<br>6. While taking a job interview, I worried about whether I was a good candidate for the job.<br><br>**Behavioural Anxiety**<br>1. During a job interview, my hands shook.<br>2. It was hard for me to avoid fidgeting during a job interview.<br>3. My heartbeat was faster that usual during job interviews.<br>4. Job interviews often made me perspire (e.g., sweaty palms and underarms).<br>5. My mouth got very dry during job interviews.<br>6. I often felt sick to my stomach when I was interviewed for a job. |
| Note. Items are rated on a 5-point response scale:<br>1=strongly disagree, 2=disagree, 3=feel neutral, 4=agree, 5=strongly agree |

Table 3.4: Items for Measure of Anxiety in Selection Interviews (McCarthy & Goffin, 2004)

#### 3.4.3.3 Semi-structured Interview

A semi-structured questionnaire was designed to obtain both personal data and information on the participant's subjective experience during the VR exposure. The semi-structured interview examined five areas, which were: task difficulty, immersion, presence, anxiety, and after-effects. The interview questionnaires were based on traditional immersive and presence questionnaires (Witmer & Singer, 1998). The interview questionnaires asked about the details of participants' VR experiences across five topics (Table 3.5).

**Q1. Task difficulty**
How did you feel about the job-interview questions? Were they difficult to understand or tough to answer?

**Q2. Immersion**
When you took the virtual job interview, did you often think to yourself that you were actually in the office? Please tell me about your experience of the virtual job interview.

**Q3. Presence**
Did you think of the interviewer as images that you saw or did you feel as though you were interacting with a real person? Could you tell me more about your experience when you faced the interviewer?

**Q4. Anxiety**
Do you think this virtual job interview can produce any anxiety or nervousness? How about your experience? Did you feel any anxiety or nervousness during the virtual job interview?

**Q5. After-affects**
Did you feel any discomfort such as dizziness or eyestrain during VR exposure? If you felt such sickness, please tell me about your feeling now.

Table 3.5: Interview Questionnaires

The open-ended interview allowed richer and more varied responses to be obtained from the individual interviewees. The interview transcripts were analysed using the five-stage approach for qualitative data (Pope *et al.*, 2002) : familiarisation with data, identification of a thematic framework, indexing, charting, and mapping and interpretation (Figure 3.16).

***Familiarisation***- the raw data or a pragmatic selection from the data was familiarised by listening to recordings, reading transcripts, and studying notes, in order to list key ideas.

***Identifying a thematic framework*** - the raw data was examined to discover in general all the key answers within the five themes; this was carried out by

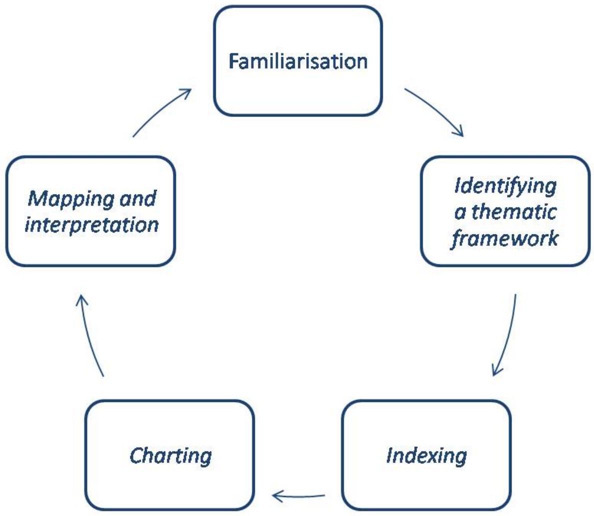



Figure 3.16: Five Stages of Data Analysis in The Framework Approach (Pope et al., 2002)

highlighting sentences on transcripts.

***Indexing*** - in this stage, the highlighted data was labelled and indexed for future retrieval and investigation. Indexing was applied to all the data in textual form by interpreting the transcripts with numerical codes and short text description (e.g. I felt nervous at the beginning of the exposure [3-A1: Anxiety] )

***Charting*** - the indexed data was rearranged according to the appropriate theme. Unlike simple cut and paste methods, the charts contain refined summaries of views and experiences.

***Mapping and interpretation*** - using the charts, the key findings were identified and interpreted.

The interview was conducted at the end of VR exposure. The conversations were audio and video recorded and transcribed, and then analysed using the approach that has been mentioned above. All work was completed with the assistance of computer software for data management.

## 3.5 Quantitative Analysis Method

In this study, the outcomes from quantitative measures were carried out mainly using the ANalysis Of VAriance (ANOVA) in SPSS 15.0. This analysis method is an authoritative set of procedures used for analysing significance where two or more conditions are used (Girden, 1992). The significant decision implies rejecting or accepting the null hypothesis ($H0 : \mu1 = \mu2$). The null hypothesis is rejected when the probability (p value) that a result occurring under it is less than 0.05 (5%). In general, ANOVA compares the variance of the sample means with the within groups variance. Within groups variance is computed by taking the average of the variances within each sample. When the result of ANOVA suggested rejecting the global null hypothesis, the mean comparisons for different levels of factors were performed using the Sidak multiple comparison correction in order to examine the probability from the individual differences by multiplying each p-value by the entire number of comparisons (Glantz & Charlesworth, 2005).

## 3.6 Summary

This chapter described the methodology of this research and understand the research process itself. In the first part of this chapter, the scope of investigation was determined by drawing on a priori issues and research questions derived from the aims and objectives of the research. The second part was concerned with the strategy of experimental design. Thirdly, the technical description of the virtual job-interview simulation was outlined in section 3.3. Based on the fundamental knowledge of human factors in VR, a high graphical fidelity of virtual job-interview simulation was developed in collaboration with the Centre of Warwick Careers Service and Warwick Medical School. In order to provide flexible settings so that the investigation could address multiple research aims, two different types of VR system were developed. In section 3.4, various measurements were introduced to assess the levels of anxiety. Due to the complexity of anxiety measure and the lack of a predominant single measurement, this research determined to use a combination of behavioural, physiological, and verbal measurements. Both quantitative and qualitative analysis methods were utilised to assess the levels of anxiety during the experiments. The experiment on user testing for the acceptance of VR simulation as an anxiety-stimulating environment is reported in Chapter 4, while Chapters 5 and 6 describe two experiments that were conducted to address research questions.

CHAPTER 4

# Preliminary Study

As the first stage of research, a preliminary study was conducted to explore user experiences of the initial version of the virtual job-interview simulation, and to identify recommendations for improvement before the main experimental study began.

## 4.1 The Objectives of the Preliminary Study

The study tried to identify how well the virtual job-interview simulation was able to provoke both anxiety and the feeling of presence within potential users. This preliminary study was designed to acquire a basic set of data in terms of the participants' responses during the virtual exposure. This study focused on the observation of participants' eye-contact avoidance and eye-blink which are both characteristic anxiety responses. In addition, the participants' perspectives on the VR experience were captured through semi-structured questionnaires. This subjective measure, together with the measures of eye movement, was used to determine the degree of anxiety and presence.

## 4.2 Material and Task

The job-interview scenario consisted of two 3D job interviewers (Man and Woman). These were designed with commercial 3D modelling software (Maya 8.0). The software employed various state-of-the-art techniques to animate lifelike attitudes (Figure 4.1). The details of these modelling techniques were described in Chapter 3.3.

Figure 4.1: The Models of 3D Job Interviewer

Previous work has shown that a negative-avatar scenario can make participants feel uncomfortable and elicits sufficient anxiety in VR exposure (Pertaub *et al.*, 2002). Based this finding, the virtual interviewers were programmed to animate with negative or positive reactions as anxiety stimuli. As can be seen by Figure 4.2, the interviewer on the left side (VR-M) performed very encouraging reactions to an interviewee, such as frequently smiling and nodding during the job interview.

Figure 4.2: Virtual Interviewers (Left VR-M and Right VR-W)

The woman interviewer on the right side (VR-W) gave dissatisfied reactions such as head-shaking, avoiding eye-contact and yawning.The interviewers asked five general job-interview questions which were:

*VR-M: Could you introduce yourself?*

*VR-W: What have you most enjoyed about being at The University of Warwick?*

*VR-M: Give me an example of when you have had to work on a problem in a team.*

*VR-W: What newspaper do you read and why?*

*VR-W: Where do you see yourself in five years' time?*

The virtual job simulation was rendered by NVIDIA Geforce 8800 GT TurboCache with the resolution mode of $1280 \times 800 \times 32@60hz$ and presented on a large-sized LCD TV (57 inch) in a dark room setting. The room was dressed as an executive board room to make participants feel as if they were in a real job interview. Sounds were delivered by 2.1ch speaker (Logitech). All animations and sounds of the avatars were triggered by an investigator in a real-time control interface. A dividing wall was set up to visually isolate the virtual job-interview environment from the investigator and the rest of the lab.

## 4.3 Measurements

It is well known that escape and avoidance behaviours are widely applied in social anxiety. In particular, the avoidance of eye contact is one of the major symptoms in social phobia (Wells & Clark, 1997), as well as having an influence on the potential success of a job interview (Heimberg *et al.*, 1986). Eye-contact avoidance behaviour is associated with increased anxiety levels, as this has been verified by the studies of Horley *et al.* (2003) and Grillon *et al.* (2006). In order to observe the tendency of participants' eye-contact behaviours, an eye tracker was used with the baud rate at 60 samples per second. This study measured how often participants spent gazing at the interviewer's face during the course of the job interviews (Figure 4.3).

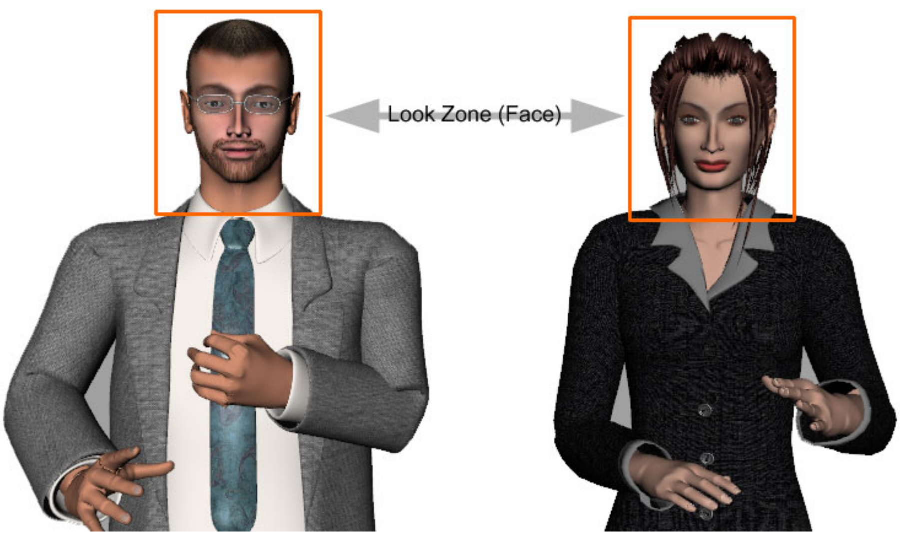



Figure 4.3: Look-Zone Area (Face)

The points of gaze fixation on the face area (LZ) were numerated and then the percentage out of the total gaze fixation points was calculated by the following equation (Equation 4.1):

$$PGF = \left(\frac{\alpha GP}{\gamma GP}\right) \times 100 \quad (Equation 4.1)$$

PGF: The percentage out of the total gaze fixation points on LZ in each question

$\alpha GP$: The number of gaze fixation points on LZ in each question

$\gamma GP$: (the end of time - the start of time (Sec.))×60 of each question

Eye-blink is associated with an increase in sympathetic nervous system activity (Gross & Levenson, 1993). Thus, this study measured how the participants' rate of eye-blink varied to identify the capacity of the virtual job-interview simulation to provoke anxiety. The blink measurement in the eye tracker which reported the occurrence of blink events was a binary signal: true or false. PERCLOS threshold was set up to 0.75 to distinguish between regular short blinks and eye closure (Figure 4.4).

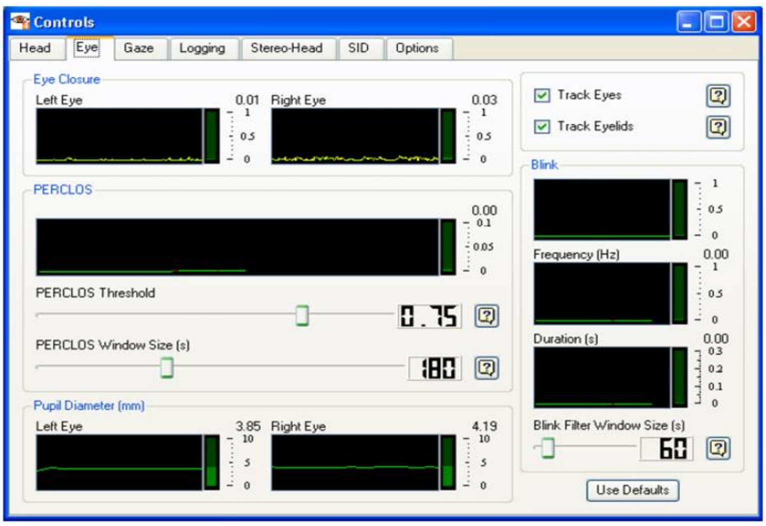



Figure 4.4: Screen of the Eye-blink Detection Set-up Module

The rate of blinking was calculated by the equation 4.2.

$$REB = \left(\frac{\alpha EB}{\gamma EB}\right) \quad (Equation 4.2)$$

REB: The rate of eye blinks per second in each question

$\alpha EB$: The number of eye blinks in each question

$\gamma EB$: (the end of time - the start of time (sec.)) of each question

In addition, a semi-structured questionnaire was used to obtain details of a participant's VR experience within five given issues: task difficulty, the sense of immersion, the sense of presence, anxiety, and after-effects (Table 3.5).

## 4.4 Selection of Participants

Six students from Warwick University participated in this initial study to test the prototype of the virtual job-interview simulation in terms of anxiety-provoking, and to identify their recommendations for improvement of the simulation before the main experimental study began. In order to recruit individuals who have never experienced a formal job-interview or are afraid of their upcoming job-interview, the participants were recruited using the snowball sampling method which is convenient to find hidden potential users, such as those with anxiety who may not readily volunteer in response to a general advertisement (Bryman, 2001). We found one participant in the University, and then further participants were sought from amongst their acquaintances. This convenience sampling strategy provided the least cost to the investigator, in terms of time, effort and money (Marshall, 1996). It does not provide a representative sample in the way that, for example, random sampling would. However a generalisable representative sample was not required for prototype testing. Instead it was important to obtain a small sample of users who met the criteria for using the intervention. The aim of this preliminary work was to assess the usability of the system, to identify potential barriers to using the system, and to explore whether the intervention worked for potential users, and thus the snowball system was deemed most appropriate.

Rationally, with larger sample sizes, the number of identified problems should be expected to increase. However, Blair *et al.* (2006) demonstrated that the most serious problems can be detected with small numbers of interviews even if samples increase the possibility of identifying exceptional problems. Moreover, Nielson & Landauer (1993) verified that five or six users are sufficient to find the main problems in a usability test for a system. As mentioned earlier in this chapter, the main objective of this study was to identify general ambiguities for adjustment of the initial version of virtual job-interview simulation. Thus, qualitative approaches were mainly used to obtain the perspectives of participants on the virtual job-interview simulation and to observe their behavioural reactions in terms of anxiety provoking. We believed that six participants were adequate to establish the feasibility of the system and to identify any major technical issues.

## 4.5 Characteristics of Participants

Six individuals were recruited with using the above strategy (Section 4.5). Most of the participants were afraid of their upcoming job-interview, and some of them had never experienced a formal job-interview. The following table (Table 4.1) shows the characteristics of participants in this study.

The ethnic background was three males and three females, aged from 22 to 27 years old, four of whom were Asian (Chinese, Korean, and Indian) and two European (Spanish and British). Three of them were postgraduate students (Master's Degree) and the others were final-year undergraduate students. In order to identify equivalence among all participants regarding their trait to social anxiety in

| Participants | Gender | Age | Nationality | Degree | Job-Interview Experience | LSAS* | Baseline of Eye-blink (per sec.) |
|---|---|---|---|---|---|---|---|
| A | Male | 25 | Chinese | P.Grad† | Y | 52 | 0.22 |
| B | Male | 22 | Korean | U.Grad‡ | N | 48 | 0.18 |
| C | Male | 27 | Korean | P.Grad | Y | 61 | 0.24 |
| D | Female | 23 | British | U.Grad | N | 49 | 0.20 |
| E | Female | 24 | Indian | P.Grad | Y | 55 | 0.21 |
| F | Female | 22 | Spanish | U.Grad | N | 32 | 0.15 |

*LSAS (Liebowitz 1987): Liebowitz Social Anxiety Scale (Total score = 144), †P.Grad: Post-graduate student, ‡U.Grad: Under-graduate student

Table 4.1: The Profiles of Participants

real life, we tested the severity of their anxiety using the Liebowitz Social Anxiety Scale (LSAS). The average score was 56.14 (SD = 5.34) out of the total of 144. According to the score table in LSAS (Liebowitz, 1987), four participants scored less than 55, which meant that they did not meet any symptoms of social anxiety disorder. Two of them had moderate social phobia.

## 4.6 Experiment Procedure

After a brief introduction to the purpose of the study and an explanation of the devices, each participant was asked to give consent to this research (Appendix B.3). Later on during the introduction session, the participant's gaze position was calibrated to compute coordinates of the target point in a 1280 × 800 pixels square covering the field of view (57 inch). After a three-minute baseline recording for eye-blink, participants were exposed to the virtual environment with the corresponding virtual interviewers and sounds. The virtual-job-interview lasted around five minutes. At the end of the virtual job-interview session, the questionnaire was administered in order to obtain the participant's view of the virtual job-interview experience.

## 4.7 Results

***The results of eye-avoidance behaviour***

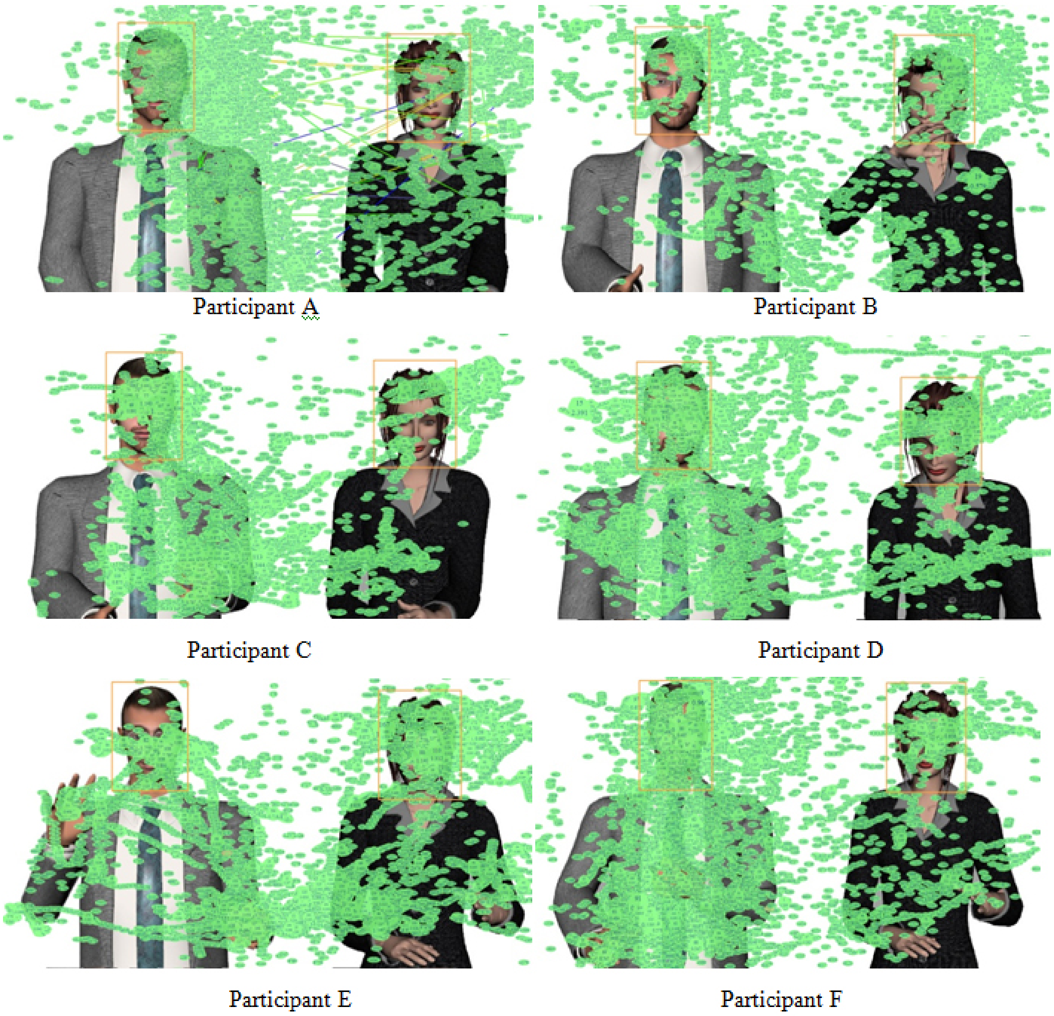



Figure 4.5: Distribution of Gaze Fixation Points

The eye tracker captured participants' gaze movements with an average of 88% tracking time success. The captured data were visualised to the points of gaze fixation and eye scan-path. Figure 4.5 illustrates the distribution of gaze fixation points which were produced by the participants during the virtual job interviews.

Although the participants did not present similar results on the points of gaze fixation, most of them tended to gaze more at the left side (VR-M), where the avatar responded in a friendly manner, than at the right side interviewer (VR-W), who reacted with unsupportive attitudes. The following charts illustrate the percentage of gaze fixation in each job-interview question. In most cases the percentage was high in the positive interviewer (Ave. = 12%) and low in the negative interviewer (Ave. = 7%)(Figure 4.6).

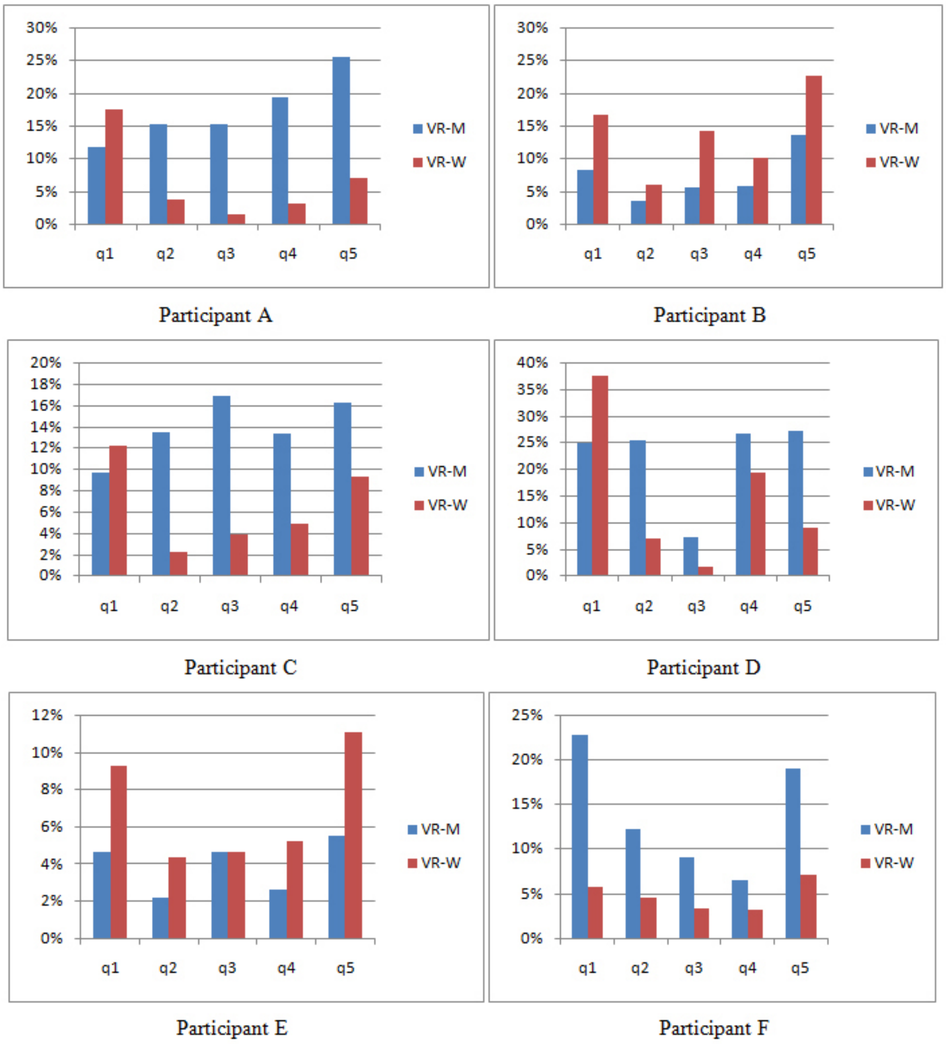



Figure 4.6: The Results of PGF

As can be seen from Figure 4.6, participants B and E reacted in an entirely unexpected way. B and E made eye-contact more with the negative interviewer, and the percentage of gaze fixation was also much lower than for the other participants. After reviewing their whole data set of gaze fixation, their gaze points were often outside of the field of view. This means that both participants B and E frequently looked at the outside of the display during the virtual job interview, causing the unexpected outcomes to appear.

While this preliminary study was not sufficient to give a firm conclusion, it can be noted that eye gaze avoidance can be elicited by the virtual job-interview simulation even when a participant has no symptoms of social phobia, and this may be related to the interviewer's negative reactions.

***The results of eye-blink***

The eye-blink provided imperative evidence to identify whether the job-interview simulation was capable of eliciting anxiety. Figure 4.7 shows how the REB increased over the course of the virtual job interview. The REB gradually increased during the virtual job interview. On average, the REB doubled (average=1.9 times) over the course of the job interview compared to the baseline recording. These results suggest that the virtual job-interview simulation provoke anxiety as measured by sympathetic nervous system activity at least to some degree.

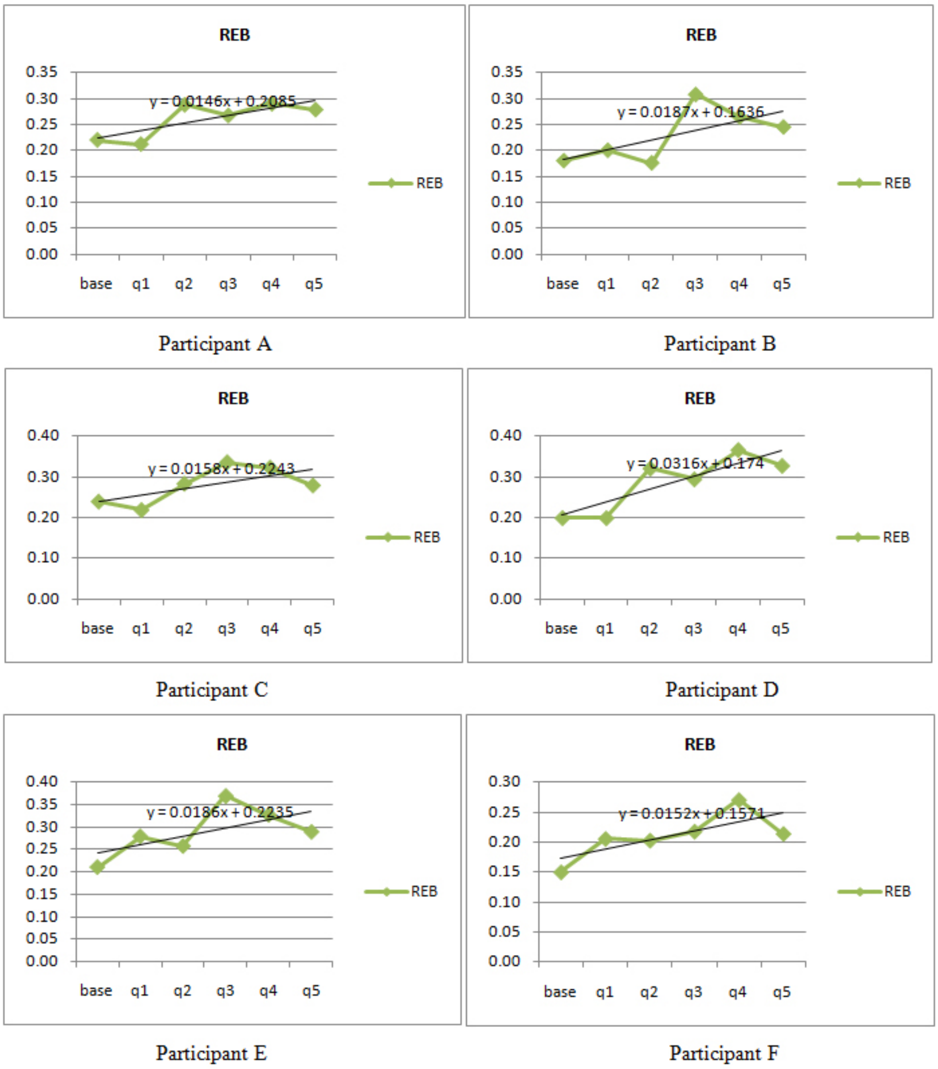



Figure 4.7: The Results of REB

### ***Result of Questionnaires***

All six participants provided comments on their experience of the virtual job interview at the end of the experiment, as follows:

**✓*How did you feel about the job-interview questions? Were they difficult to understand or tough to answer?***

None of the participants felt any difficulty understanding or answering the questions in general. Most of them said that the job-interview questions were easy and to be expected owing to the questions being common in handbooks for successful job interviews. But two of them complained about difficulty in understanding the second question (*Give me an example of when you have had to work on a problem in a team*) and the final question (*Where do you see yourself in five years' time?*) due to the speed of the question.

✓ ***When you took the virtual job interview, did you often think to yourself that you were actually in the office?***

Overall, most participants reported that it was an exciting experience and felt a similar feeling to being in a real job interview. However, participant A and C did not agree with a feeling of immersion, although they had felt unhappy about the woman interviewer who reacted negatively.

✓ ***Did you think of the interviewer as images that you saw or did you feel as though you were interacting with a real person?***

Five participants reported that the interviewer looked realistic, and generally accepted the appearance of the interviewer. Only participant C had a different opinion and commented that the interviewer seemed robotic rather than human, and that the animations were slightly unnatural (*e.g. no eye blinks, no mouth movements when speaking, and not smooth when moving fingers*).

✓ ***Do you think this virtual job interview can produce any anxiety or nervousness? How about your experience? Did you feel any anxiety or nervousness during the virtual job interview?***

All participants reported anxiety during the virtual job interview, at least to some degree they made comments such as "*actually it made me really nervous*", "*I was really dithering*", "*At the beginning of this interview I felt like it was fun, but I was getting serious by the end*", and "*well, not too much but I was sweating*".

✓ ***Did you feel any discomfort such as dizziness or eyestrain during***

***VR exposure? If you felt such sickness, please tell me about your feeling now.***

There were no negative comments on after-effects.

Overall, participants often thought to themselves that they were actually in an interview room and to an extent felt as though they were interacting with a real person. From the results of the verbal comments, most participants reported similar feelings of nervousness to those they experienced in a real job interview. Some of them complained about the speed of the interviewer's speaking and unnatural animations. These inconveniences might be reflected in further experimental study.

## 4.8 Discussion

The preliminary study aimed to identify whether a virtual job-interview simulation could provoke anxiety. Two virtual job interviewers were designed who between them would ask five common job-interview questions. During the virtual job interview, one interviewer reacted positively and the other reacted negatively. Three measurements - eye-contact, eye-blink and short-questionnaire - were used to observe participants' tendencies of eye-movement and their perspectives on the experience of the VR interview.

Some interesting results can be found from this study. The virtual job-interview simulation was generally able to induce the avoidance of eye-contact in relation to the interviewer who reacted negatively and provoke a feeling of nervousness to some degree. While the virtual job-interview simulation was successful in stimulating anxiety-related behaviours, several limitations can be found from the job-interview simulation itself and from the measurements.

*Material*

Five common job-interview questions were asked during the virtual job interview, but several participants complained about the speed of speech. Most participants were not native English speakers, thus they often felt difficulty understanding the job-interview questions when they were spoken too fast. Furthermore, the virtual job- interview simulation was still limited in stimulating anxiety. The simulation could be improved with better sound and visual quality, more natural animations of avatars, and even tactile stimuli, but also be able to interface the bio-feedback material to determine the levels of anxiety of the participants.

*Measurements*

An eye tracker was used to monitor participants' eye-contact avoidance and blink behaviour with a visual and real-time approach. However, this device had a limitation in dark environments. Although this study used the latest technology of eye tracking device, it sometimes failed to capture a participant's gaze position, with an average of 12% of tracking time being lost. Thus, a solution should be found to lower this failing rate. Furthermore, the semi-structured questionnaire allowed us to capture details of participants' experiences of virtual exposure, but it was difficult to determine actual levels of anxiety or nervousness. For further measures of levels of anxiety, other measurements could be used (*e.g. heart rate, skin conductance responses, or self-rating scales*) in future studies.

## 4.9 Summary

The results of this preliminary study were used to inform the main experimental study. This study gave confidence that the computer graphics simulation for the job interview was able to provoke some degree of anxiety or nervousness. However, action needed to be taken to remedy some of the shortcomings that have arisen as explained above. The design and results of the two major studies are presented in chapters 5 and 6.

CHAPTER 5

# Social Anxiety and Visual Realism in VR

The sense of presence has been regarded as an important factor in the development of virtual environments. Presence is influenced by several variables in VR, such as ease of interaction, maximal pictorial realism, length of immersion in the virtual environment, and so on (Slater & Usoh, 1995). Several studies have demonstrated a significant correlation between the human factor and the individual's anxiety level in VR therapies (Robillard *et al.*, 2003 and Huang & Alessi, 1999). Robillard *et al.* (2003) evaluated the relationship between the factor of cyber-sickness and anxiety levels. Huang & Alessi (1999) suggested the impact of the sense of presence on emotional states in VRET through literature-based study. Due to the limited evidence about the relationship between human anxiety and the factor of presence in VRET, this experimental study was conducted to investigate the correlation between the graphical realism of VR and the individual's anxiety levels in VRET for social phobia. Based on the previous work, this study assumed that more graphical realism of VR would induce a higher sense of presence, and thus would provoke more anxiety. To verify the assumption, this study focused more on how the level of anxiety varies in accordance with different graphic details of avatars in an anxiety-provoking virtual job-interview simulation. This finding might contribute to the development of a specific VRET for social phobia care which enables a patient to be exposed to a simulated anxiety-provoking situation in a controlled manner, and which allows the anxiety stimulus to be adjusted according to the specific needs of the patient. The objectives of this study and research questions have been detailed in Section 3.1.2.

## 5.1 Experiment Methods

This section outlines the detailed experiment methods, including the explanation of materials, the selection of participants, experiment design, and measurements. The methods were concerned with concentrating on extending the previous preliminary study outlined in Chapter 4.

### 5.1.1 Virtual Job-interview Simulation

Three different graphic levels of avatar were developed from a low level of graphic fidelity to a high level of graphic fidelity: a photograph textured interviewer (VR1), a cartoon-like 3D interviewer (VR2), and a realistic 3D human interviewer (VR3) (Figure 5.1). The human photo model (VR1) was designed by the technique of texture mapping on 3D object surfaces. The texture that was used correlated to three photographs of a real interviewer that represented neutral, positive and negative postures (Figure 5.2). The model of the realistic 3D interviewer (VR3) was created using Autodesk's Maya software package. In order to simulate a realistic approach, the virtual interviewers were modelled with a layered hierarchy. A virtual skin was attached to a basic skeleton that animated the whole body. The skeleton consisted of a number of segments, which were connected to each other by the joints. The animation of the skeleton was performed by four-dimensional matrices guided by inverse kinematics and key-frames. To obtain a high degree of realism for facial animations, deformation techniques were applied to the avatar, such as a blend shape and key-frame to create various facial expressions (Section 3.3). In addition, the cartoon-like 3D interviewer (VR2) was created using the same techniques as the 3D interviewer (VR3), but in much less detail and with a view to the artistic guidelines of cartoons.

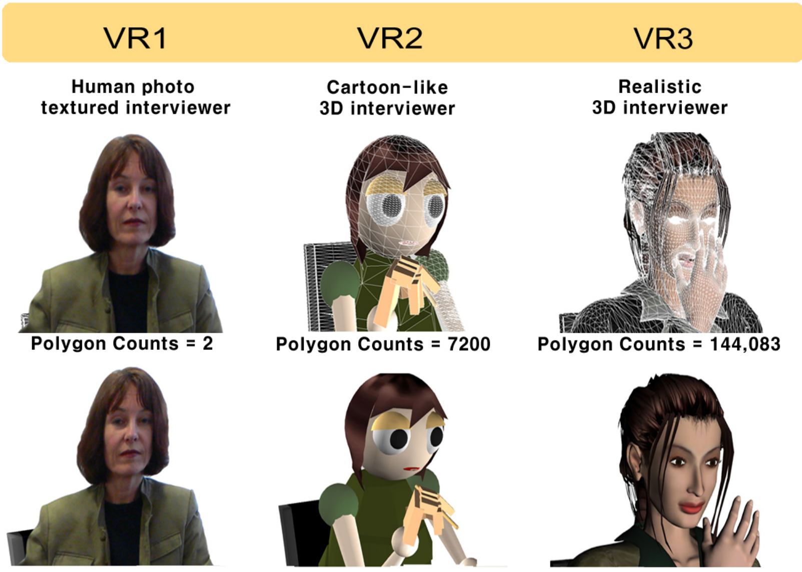



Figure 5.1: Different Fidelity Levels of Virtual Humans were used. From left to right: Human Photo Textured Interviewer (VR1), Cartoon-like 3D Interviewer (VR2), and Realistic 3D Interviewer (VR3)

The 3D models (VR2 and VR3) were programmed to express various animations. They could move lips and blink eyes, and they could express negative or positive reactions such as smiling, nodding, head-shaking, yawning, turning away, avoiding eye contact, interlocking fingers and looking interested, folding arms and looking disinterested, and so on. To enhance the realism of the virtual interviewers, a set of sound clips were used. For example, the virtual interviewers could ask job-interview questions, and say phrases such as, "*Thank you*", "*Yes*", "*I have heard enough*", "*Ok I am going to go to the next question*", and, "*That sounds interesting, could you tell me more please?*"

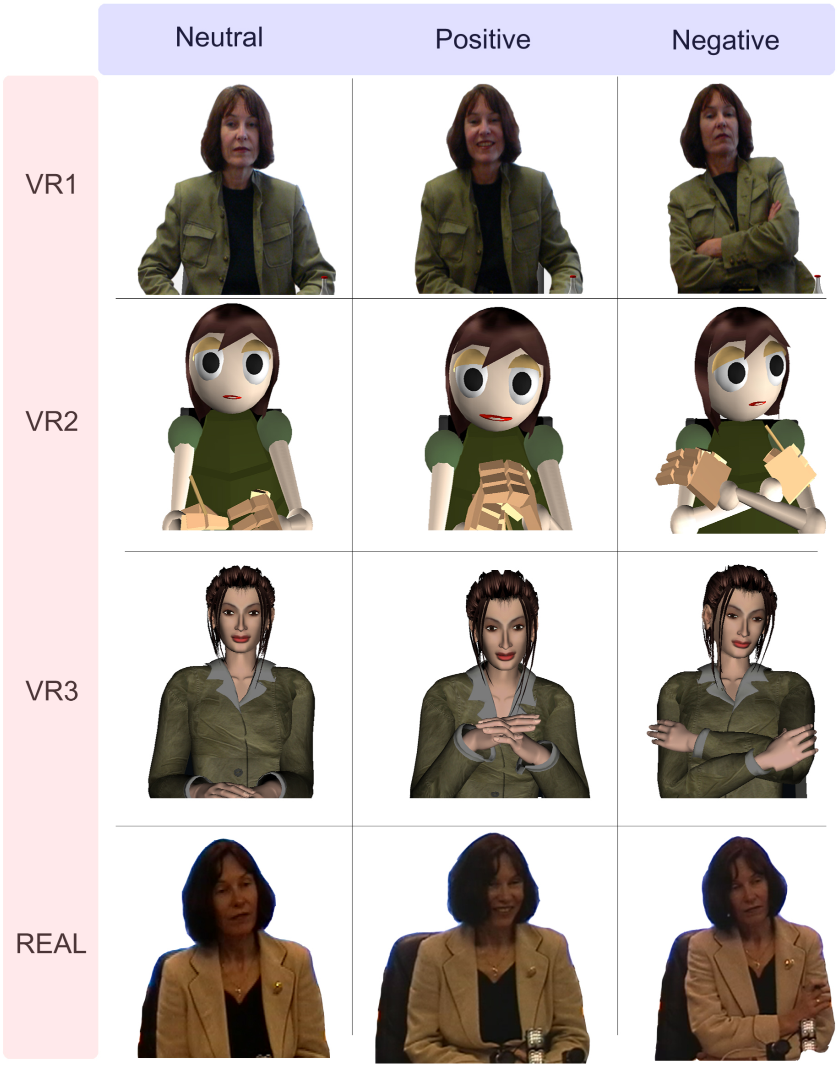



Figure 5.2: Three Types of Reactions. From left to right: Neutral, Positive and Negative

The interviewer asked nine general job-interview questions in a random sequence to all participants. The interview questions were delivered by 2.1ch audio output. The interview questions were:

- ✓ *What have you most enjoyed about being at university?*
- ✓ *Why do you want to work for us?*
- ✓ *Give me an example of when you have had to work on a problem in a team.*

✓ *How do you cope under pressure? Give me an example of when you have had to cope in this way.*

✓ *Tell me about a time when you used your skills of persuasion to convince someone of your ideas.*

✓ *How has your work experience informed your commercial awareness?*

✓ *Tell me about a time when you made a mistake and overcame it. What did you learn from the experience?*

✓ *What newspaper do you read and why?*

✓ *Where do you see yourself in five years' time?*

When participants were delivering their answers, the interviewer reacted in a neutral way for the first three answers (*e.g. smiling or nodding*), negatively for the next three answers (*e.g. head-shaking, yawning, turning head away with the sound of a sigh, and saying negative phrases like "Ok, I have heard enough"*) and in a positive manner for the final three answers (*smiling, interlocking fingers and looking interested, with encouraging phrases such as "That sounds interesting, could you tell me more please?"*) Moreover, to interrupt the participants' answers if they were too long, several breaking-off expressions were implemented such as, "*Thanks for your answer*" or "*Ok, I am going to go to the next question.*" The selection of all the sounds and animations was able to be operated by the investigator at any time during the job interview (Table 5.1).

The virtual job interview was simulated via Virtools (VR engine), which the animation and voice of virtual humans to be triggered in real-time as and when required. The virtual job-interview situation was presented on a 57-inch LCD TV with 1080p resolution. The VR solution was combined with additional devices such as an eye tracker (Facelab4), a bio-feedback amplifier (Psylab), a web

| Question | Reaction Type | Animations | Sounds |
|---|---|---|---|
| From 1st to 3rd | Neutral | Deadpan, Smiling, or Nodding | Yes, or Sure |
| From 4th to 6th | Negative | Head-shaking, Yawning, or Turning head away (avoiding eye contact) | Sigh, or Ok, I have heard enough |
| From 7th to 9th | Positive | Big smiling, Nodding, or Interested looking with interlocking fingers | That sounds interesting, could you tell me more please? |

Table 5.1: Three Types of Reactions (From top to bottom: Neutral, Negative and Positive)

camera (QuickCam S5500), and a video recorder (6mm digital) (Figure 5.3). The recorded videos were saved to hard disk, and secured with password protection.

Figure 5.3: Experiment Settings. From left to right: Virtual Job Interview and Real Job Interview

### 5.1.2 Measurements

As discussed in Chapter 3, anxiety is often associated with multifarious cognitive, somatic, emotional and behavioural features. Due to the complexity of the various aspects of anxiety, this study employed a combination of physiological, behavioural and verbal measures to determine the level of anxiety that participants experienced when exposed to VR simulation.

#### *Physiological measurements*

Physiological measurements related to anxiety were taken: Pulse Rate (PR) and Skin Conductance Response (SCR)(Section 3.4.1). The data for PR and SCR was collected by Contact Precision Instrument's amplifier. Customised analysis software was applied to pre-process the data and to remove movement-related artefacts. PR was calculated as the average number of beats per minute for the duration of each interview question (Equation 3.1). In the same way, the mean of skin conductivity startle level was calculated for the duration of each interview question (Equation 3.2).

#### *Behavioural measurements*

Eye-avoidance behaviours have been measured in several studies as an important marker to identify social anxiety. Horley *et al.* (2003) verified that individuals with anxiety were characterised by a lack of gaze fixations, both in number and duration, and remarkably increased raw scan-path length. Grillon *et al.* (2006) successfully measured eye scan velocity and blink through an eye tracker to identify the level of anxiety that was produced by participants during their virtual reality exposure sessions. The present study observed each participant's eye-contact avoidance behaviour and the frequency of eye-blink using an eye tracking device (Section 3.4.2). In order to conduct the statistical investigation, the captured raw data was reproduced to the percentage of gaze fixation on the interviewer's face area (PGF), as well as the rate of eye-blink per second (REB) for each job-interview question (Equation 3.3 and 3.4).

#### *Verbal measurements*

Measure of Anxiety in Selection Interview (MASI) was utilised which is a self-rate scale to measure job-interview anxiety across five dimensions: communication, appearance, social, performance, and behavioural. However, some items were not applicable to this virtual job-interview simulation, thus the scale was modified to 18 items within the aspects of communication, performance, and behavioural anxiety. The details of this modified scale were explained in Section 3.4.3.2 (Appendix A.3).

### 5.1.3 The Selection of Participants

Participants were recruited through university emails, posters, and online banners over the course of three weeks (Appendix B.2). The study was advertised with help from the Warwick Careers Service Centre. When people notified us of their wish to take part in this study, we directly contacted them by email and sent them an invitation letter. None of the participants had taken part in the preliminary study described in Chapter 4. Participants in all conditions were told that they could withdraw from participation at any time during the course of the experiment and they were informed as to the objective of the experiment. A consent form was submitted when they agreed to this study (Appendix B.3).

A non-probability sampling method was used to determine a sample size (Bekmont, 2008) for this study. This method was not able to ecologically generalise the result with a model of statistical probability; however, it could generalise theoretical findings (Bekmont, 2008). The sampling frame for this study was final-year undergraduate students and master's students who were going to be graduating that year. The target population was limited to students at Warwick University who have never experience a formal job-interview, and were afraid of upcoming job-interviews. We decided to recruit 60 participants. According to the central limit theorem ($\sigma 2/n$), we assumed that the sample mean was approximately normally distributed because the sample size n is greater than or equal to 30 (Stephens, 1998). In order to increase the validity of results, the model of

*Within-subject Design* for this experimental study was used. This design allowed us to directly compare the responses of participants in one condition to their responses in another (Section 3.2). According to this repeated-measures model, all participants were exposed to two different VR conditions; thus, 120 samples were obtained.

### 5.1.4 Characteristics of Participants

Sixty participants (31 female and 29 male) were recruited for this experimental study. The age range of participants was 21-34 years (mean=25.95 and SD=2.84). Their ethnic backgrounds were: 47 Asian (Thai, Chinese, Japanese, Indian and Korean) and 13 European (French, Spanish, Italian, Slovakian, Norwegian, and British). In order to reduce sequence effects, the treatments were counterbalanced by test orders and conditions. The 60 participants were divided into six groups as closely matched as possible with respect to demographic and severity of symptoms. Table 5.2 describes the profile of each group and their treatment order.

| Group Name | No. Subjects | Mean of Age (SD) | The mean of BFNE score | | Session Order | |
|---|---|---|---|---|---|---|
| | | | First | Second | First Test | Second Test |
| A | 10 | 26.5 ( 3.05) | 24.9 (6.05) | 24.2 (4.12) | VR1 | VR2 |
| B | 10 | 26.0 (3.41) | 23.1 (6.70) | 23.5 (3.50) | VR3 | VR1 |
| C | 10 | 27.1 (3.21) | 24.5 (6.13) | 25.1 (3.92) | Real | VR1 |
| D | 10 | 24.5 (2.91) | 25.1 (6.39 ) | 24.2 (7.40 ) | VR2 | VR3 |
| E | 10 | 25.6 (3.89) | 24.6 (4.55) | 24.0 (5.35) | VR2 | Real |
| F | 10 | 26.0 (2.37) | 23.8 (5.59) | 23.9 (6.12) | Real | VR3 |
| | Total = 60 | 25.95 (2.84) | 24.33 (6.32) | 24.12 (7.13) | | |

Table 5.2: The Profile of Each Group

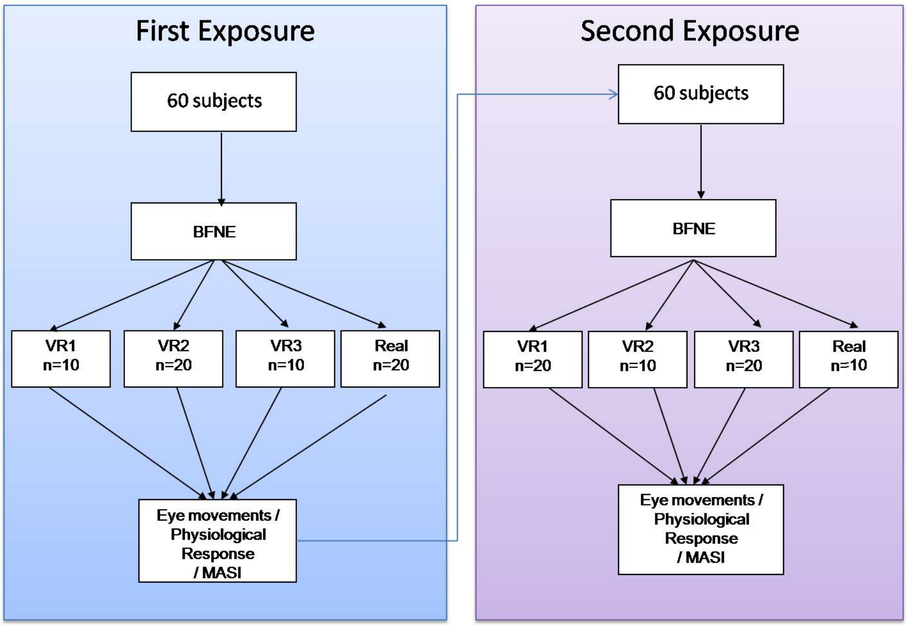



Figure 5.4: Experiment Procedure

### 5.1.5 Experiment Procedure

Before starting the job interview, every participant was asked to complete a research consent form and self-rate questionnaire: the Brief Fear of Negative Evaluation Scale (BFNE)(Section 3.4.3.1). The BFNE was employed to identify the severity of the participant's anxiety in real life, as well as to indicate sequence effects between the first and second VR exposures, which is the typical weakness of the within-subjects design. The virtual job interviews were undertaken twice by each participant, with a one-week interval. The real job interview was performed by a consultant from a University careers service. Gaze movements were collected using an eye tracker. A finger plethysmograph transducer for PR was attached to the index finger, and two electrodes for SCR were attached to the medical phalanges of the non-dominant hand. After two or three minutes of baseline physiological recordings, the mock job-interview session was started. The virtual interviewer asked nine general job-interview questions in a random sequence to all participants. In order to activate an increase in anxiety, the interviewer performed reactions over the course of job-interview. After the job-interview, the response to MASI was collected (Figure 5.4).

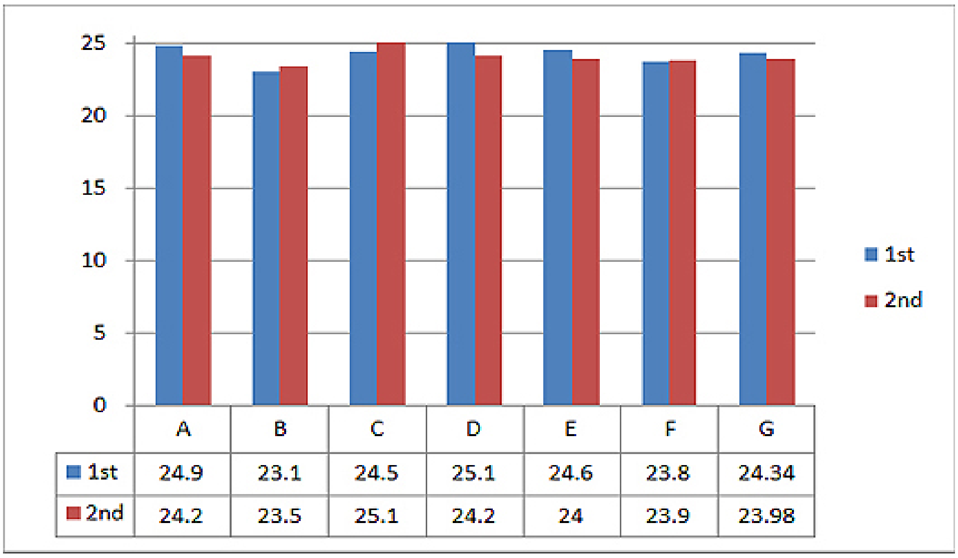
## 5.2 RESULTS

This section describes the results of this experimental study, in the following sequence: firstly, this study investigated the equivalency of characteristics among groups and practice effects between the first and second exposure. This initial evaluation for validity of the main results was conducted with the mean comparison of BFNE between groups and between exposure orders. Secondly, the results of eye movements, physiological responses, and verbal reports were analysed in order to identify the impact of the level of realism of the avatar performing the interview on the anxiety levels of the interviewee. This evaluation was carried out mainly using the analysis of Mixed Linear Models (MLM) which was estimated via restricted maximum likelihood (Hedeker *et al.*, 1994). This approach is a powerful set of procedures used for testing significance where two or more conditions are used, and takes into account the multilevel structure of the data. The mean comparisons for different levels of factors were performed using the Sidak multiple comparison correction.

### 5.2.1 Equivalency of Groups

First of all, the mean difference of BFNE was evaluated to investigate the equivalency between groups. The following graph illustrates the mean of BFNE in each group (Figure 5.5). The mean level of BFNE was shown to be virtually equal among all groups. There was no difference between the groups at 5% significant level ($p = 0.240$). This result shows that all participants were efficiently allocated into six groups without any differences in the severity of symptoms of anxiety.

Moreover, ANOVA was conducted to evaluate the mean difference of BFNE between the first and second exposure for investigating any sequence effects. As can be seen from the Figure 5.5, no evident detail can be found in terms of sequence effects. It was noticed that the mean difference between orders was not significant at 5% level ($p = 1.000$).




| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1st | 24.9 | 23.1 | 24.5 | 25.1 | 24.6 | 23.8 | 24.34 |
| 2nd | 24.2 | 23.5 | 25.1 | 24.2 | 24 | 23.9 | 23.98 |

Figure 5.5: Total Mean of BFNE in Each Group

From these evaluations, it was verified that there was no group difference regarding participants' tendency to social phobia in real life. In addition, no sequence effects could be found between the first and second exposure.

Furthermore, we conducted a test to identify any major differences in BFNE between men and women and between Asian and European group. The following Table 5.3 illustrates the differences.

| | | BFNE score | |
|---|---|---|---|
| | | Mean | Sig. |
| Gender | Male | 23.15 | 0.76 |
| | Female | 23.44 | |
| Ethnic group | Asian | 24.01 | 0.94 |
| | European | 23.91 | |

Table 5.3: Total Mean of BFNE in Gender and Ethnic Group

As seen in table 5.3, there were no statistically significant differences between the BFNE scores for male and female participants (P=0.76) or for European and Asian participants (P=0.94). We also looked for differences by gender or ethnic group for physiological responses.(Table 5.4).

| | | REB | | HR-b | | SCR-b | |
|---|---|---|---|---|---|---|---|
| | | mean | Sig. | mean | Sig. | mean | Sig. |
| Gender | Male | 0.372 | 0.38 | 7.87 | 0.22 | 2.04 | 0.43 |
| | Female | 0.375 | | 8.22 | | 2.15 | |
| Ethnic Group | Asian | 0.373 | 0.30 | 8.17 | 0.72 | 2.38 | * 0.032 |
| | European | 0.371 | | 8.38 | | 2.12 | |

Table 5.4: The Mean of Physiological Responses in Gender and Ethnic Group

Again, no significant differences were found, except for a small difference in SCR-b scores between Asian and European participants which was unlikely to have any practical significance (2.38 versus 2.12) (P=0.032). Because of these insignificant differences, the implications of gender and ethnicity differences were not considered further in this thesis.

### 5.2.2 The Results of Behavioural Anxiety Responses

In terms of a participant's behavioural anxiety responses, eye-contact and eye-blink measures were utilised to appraise the level of anxiety in different job-interview conditions. The following graphs illustrate the total average percentage of gaze fixation during which the participants looked at the interviewer's face area (PGF) in each condition (Figures 5.6).

As can be seen in Figure 5.6, the total average of PGF in VR1, VR2, VR3,

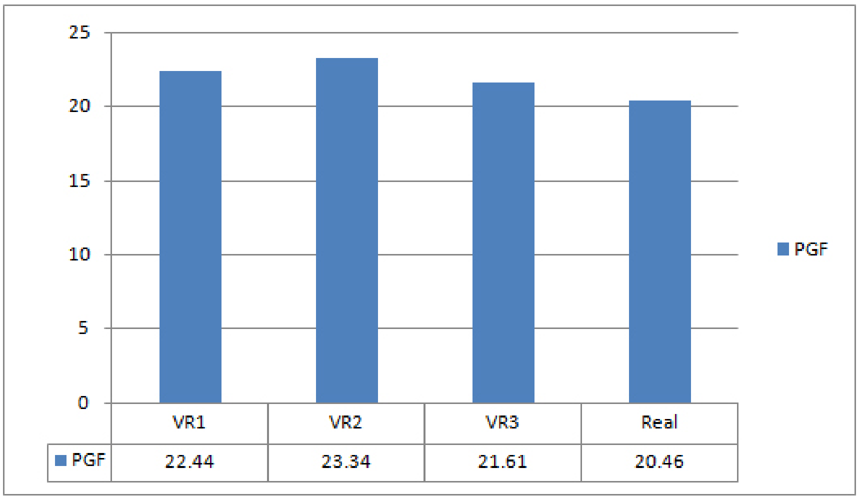



Figure 5.6: Total Mean of PGF within Four Conditions

and REAL conditions was 22.44, 23.34, 21.61, and 20.46 respectively. The mean level of PGF was lowest in the REAL condition, followed by VR3, VR1, and VR2 in that order, which indicates that the level of PGF produced by the most realistic avatar (VR3) was the closest to that produced by the real interview.

Figures 5.7, 5.8, and 5.9 illustrate the results of gaze fixation measures over the course of the job interview within four different treatments. In the real interview, the percentage of gaze fixation during which the participants looked at the interviewer's face area changed over the course of the interview. The percentage in the REAL condition decreased steadily from the first to the fifth questions, and then sharply increased during the last three questions. This tendency can be found in other treatments, excluding VR1.

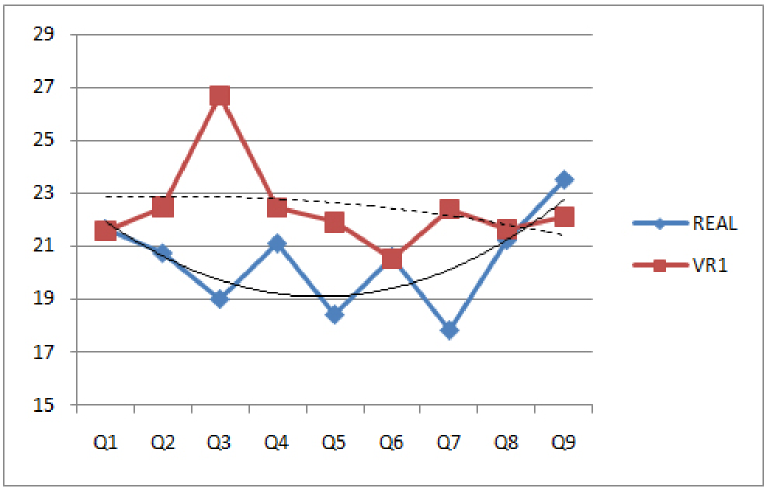



Figure 5.7: Mean Level of PGF in Every Question within REAL and VR1

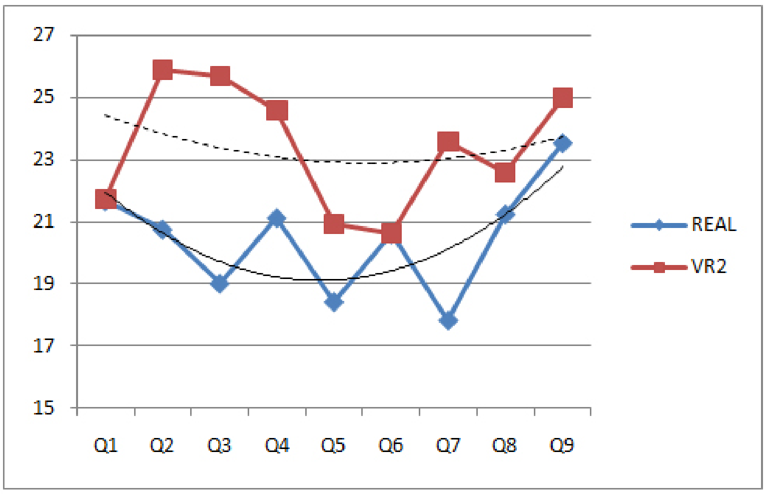



Figure 5.8: Mean Level of PGF in Every Question within REAL and VR2

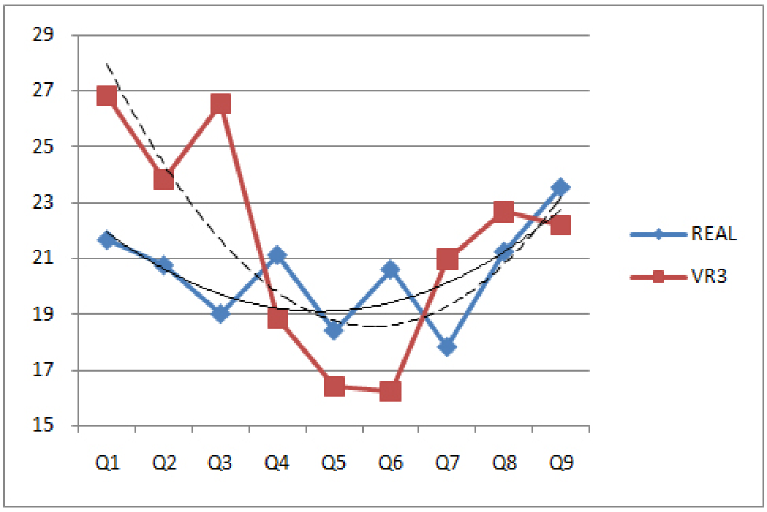



Figure 5.9: Mean Level of PGF in Every Question within REAL and VR3

As shown by the comparison of total mean levels of PGF (Figure 5.6) and their tendency changes (Figure 5.7, 5.8, and 5.9), it could be assumed that the most realistic avatar (VR3) most closely replicated the eye-contact avoidance that was observed in the real situation. In order to demonstrate this conjecture, the analysis of Mixed Linear Models (MLM) with post-hoc Sidak procedure was conducted to compare the mean difference in the four given conditions. The total mean of PGF was varied among all conditions at 5% significant level ($p = 0.003$). In the result of multiple comparisons with Sidak, It was noticed that the mean difference between VR1 and REAL ($p = 0.045$), and VR2 and REAL ($p = 0.001$) was significant at 5% level. However, the VR3 condition revealed no difference in the average of PGP compared to the REAL situation ($p = 0.150$) (Table 5.7). This result verified the assumption that the virtual situation which came closest to mimicking the gaze-avoidance behaviours observed in the real situation was VR3, the most realistic 3D avatar.

Furthermore, the rate of eye-blink (REB) was compared among the four conditions as another behavioural anxiety measure. The following graphs (Figures 5.10, 5.11, and 5.12) illustrate how the mean of REB varied over the course of the job interview. As shown in the line graphs, the tendency line of polynomial was employed to compare the difference between two conditions at an initial glance. The mean of REB in the REAL condition in particular was seen to increase from the first to the fifth question, and then gradually decrease during the last questions. This tendency was also observed in the VR3 and VR2 conditions.

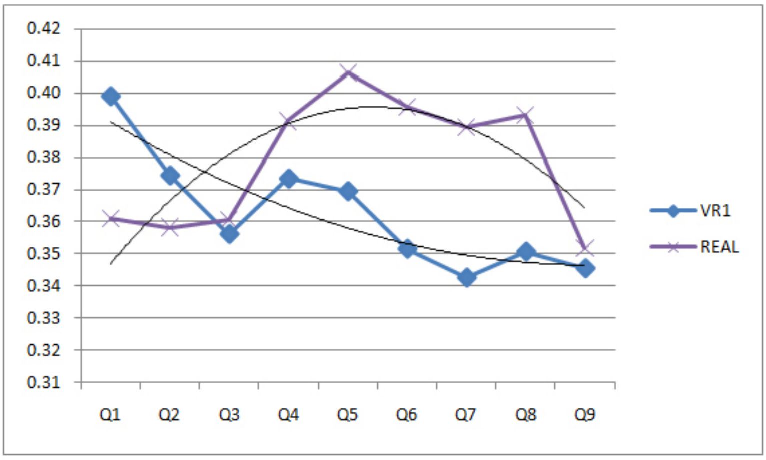



Figure 5.10: Mean Level of REB in Every Question within REAL and VR1

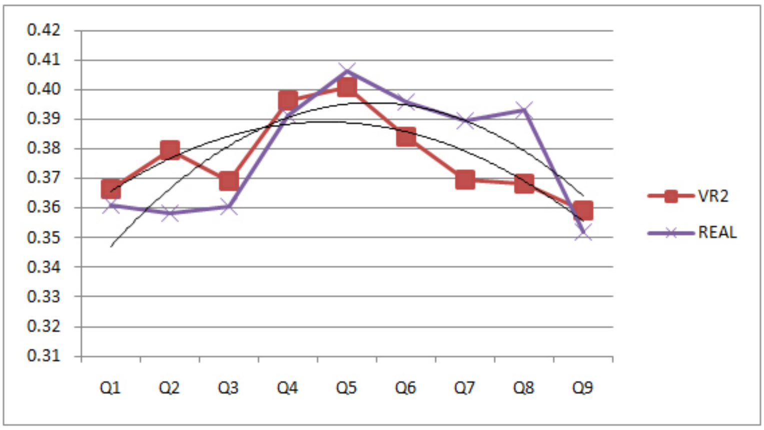



Figure 5.11: Mean Level of REB in Every Question within REAL and VR2


Figure 5.12: Mean Level of REB in Every Question within REAL and VR3

In order to investigate this tendency with statistical investigation, MLM with Sidak procedure was conducted. The total average of REB for VR1, VR2, VR3, and REAL was 0.363, 0.377, 0.371 and 0.379 respectively (Figure 5.13). The mean difference between all conditions was significant at 5% level ($p = 0.001$). No difference could be found at 5% level between REAL and VR3 ($p = 0.340$), and REAL and VR2 ($p = 0.532$) correspondingly (Table 5.7).

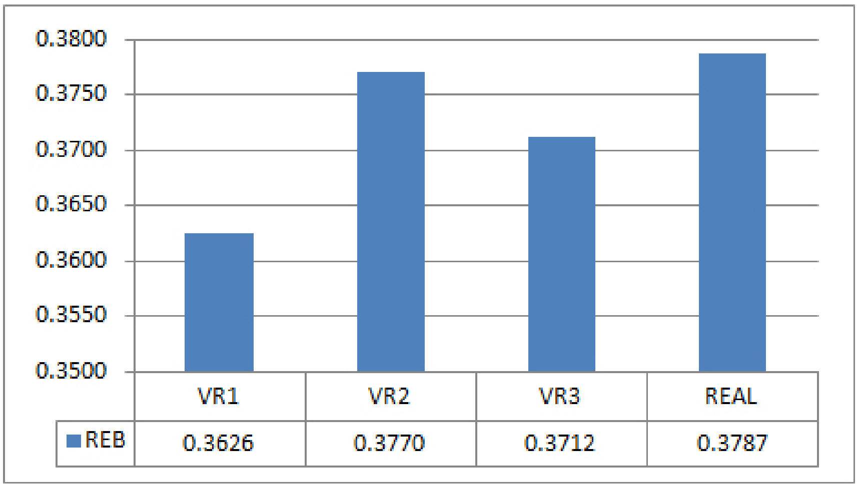
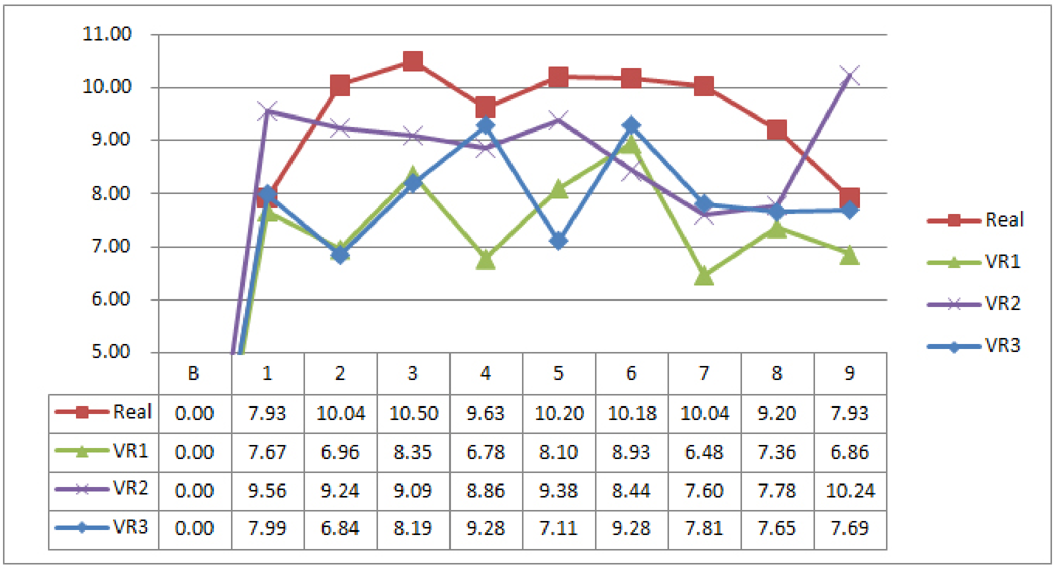



Figure 5.13: Total Mean Level of REB

In summary, this study initially evaluated a set of eye-movement data including eye-contact and eye-blink for three avatars with different levels of graphic detail and a real person over the course of a job-interview scenario. In the results of gaze fixation measure, it was noticed that the highest graphic details of avatar (VR3) induced the closest pattern of eye-contact avoidance to that observed in the real situation. In contrast, the results of eye blink measures indicated that the cartoon-like avatar (VR2) produced results that were closest to the real situation (REAL), while the condition of VR3 was also shown to produce a similar rate of eye-blink to the REAL condition. Due to the discrepancy of the results, further measures and analysis needed to be conducted.

#### 5.2.2.1 Physiological Results

The following graphs show the average of PR-b in different conditions over the course of the job interview (Figure 5.14). The graphs indicate that all conditions significantly increased the mean level of PR compared to the baseline. The REAL condition induced a marginally higher increment of PR than VR conditions. However, it was difficult to recognise the differences between REAL and other VR conditions at a glance.



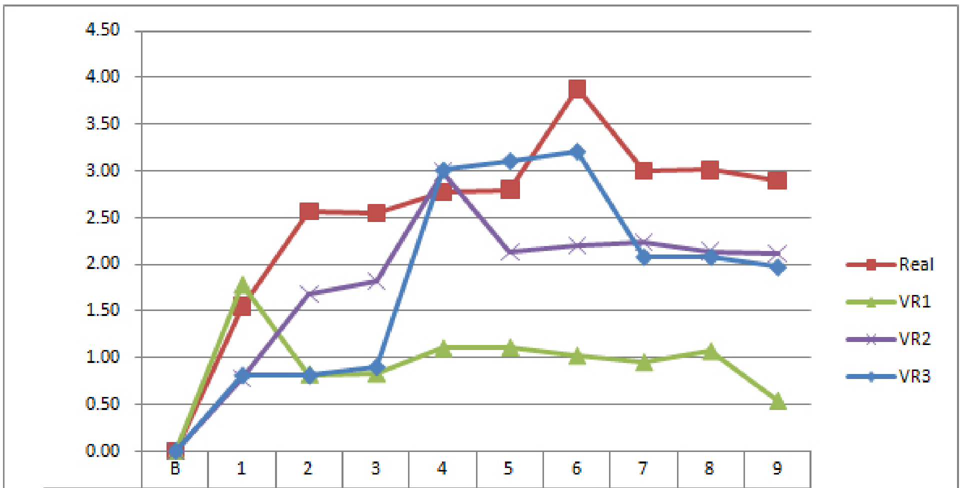
| | B | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Real | 0.00 | 7.93 | 10.04 | 10.50 | 9.63 | 10.20 | 10.18 | 10.04 | 9.20 | 7.93 |
| VR1 | 0.00 | 7.67 | 6.96 | 8.35 | 6.78 | 8.10 | 8.93 | 6.48 | 7.36 | 6.86 |
| VR2 | 0.00 | 9.56 | 9.24 | 9.09 | 8.86 | 9.38 | 8.44 | 7.60 | 7.78 | 10.24 |
| VR3 | 0.00 | 7.99 | 6.84 | 8.19 | 9.28 | 7.11 | 9.28 | 7.81 | 7.65 | 7.69 |



Figure 5.14: Mean Level of PR-B in Every Question

In order to investigate the differences between conditions with a statistical approach, the total mean of PR-b was computed. The mean levels for VR1, VR2, VR3, and REAL were 7.50, 8.28, 8.22, and 9.52 respectively. The differences between all conditions were significant at 5% level ($p = 0.016$). The difference between the real interview and each VR interview was indicated by Sidak multiple comparison correction. The difference was not significant at 5% level between REAL and VR2 and between REAL and VR3, which demonstrates that the cartoon-like avatar (VR2) and the realistic 3D human avatar (VR3) induced a greater increase in pulse rate than the photograph textured interviewer (VR1). The comparison revealed strong evidence that the conditions of both VR2 and VR3 provoked an increase in pulse rate similar to the level in the REAL condition (Table 5.7).

Next, SCR represented a different pattern of mean level compared with pulse rate. As shown in Figure 5.15, the mean of SCR-b in most conditions excluding VR1 gradually increased with visible fluctuations over the course of the job interviews. The total mean of SCR-b in VR1, VR2, VR3, and REAL conditions was 1.02, 2.01, 2.00, and 2.78 respectively. The real interviewer elicited the highest increase in a participant's skin conductance response. The difference in means of SCR-b between the real interview and each of the virtual interview situations was significant ($p < 0.05$). After conducting Sidak multiple comparison correction, It was noticed that there was no difference between VR3 and VR2 ($p = 0.989$), or between VR3 and REAL ($p = 0.051$).




| | B | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| Real | 0.00 | 1.55 | 2.57 | 2.55 | 2.78 | 2.8 | 3.88 | 3 | 3.01 | 2.9 |
| VR1 | 0.00 | 1.78 | 0.82 | 0.83 | 1.10 | 1.11 | 1.02 | 0.95 | 1.07 | 0.54 |
| VR2 | 0.00 | 0.78 | 1.68 | 1.82 | 2.99 | 2.13 | 2.2 | 2.24 | 2.14 | 2.11 |
| VR3 | 0.00 | 0.81 | 0.81 | 0.9 | 3.01 | 3.11 | 3.21 | 2.08 | 2.08 | 1.97 |

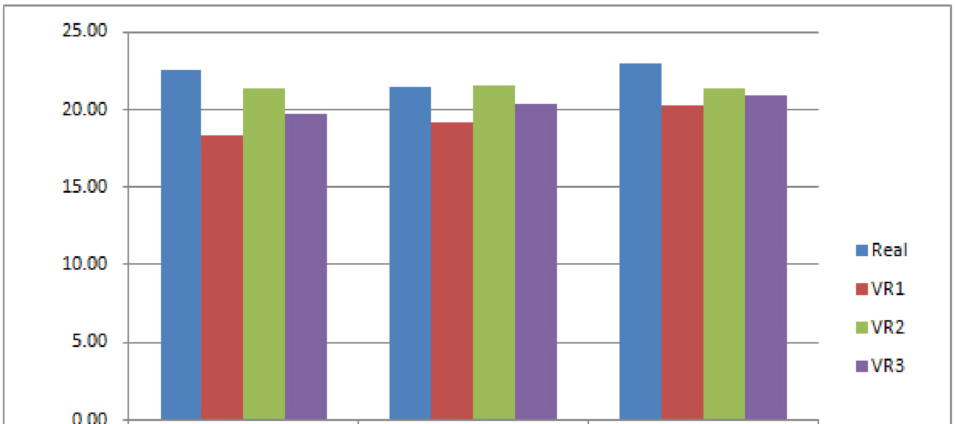
Figure 5.15: Mean Level of SCR-B in Every Question

The results from both the rise in pulse rate (PR) and skin conductance response (SCR) demonstrate the fact that the VR3 condition induced levels of physiological anxiety which came closest to replicating those observed in the real situation. In addition, it was indicated that there was no difference between VR2 and VR3 conditions, which produced the same results in both behavioural anxiety measures (eye-contact and eye-blink).

### 5.2.3 The Results of the Self-rated Questionnaire

All 60 participants submitted MASI to report their experience of the job interview, in terms of their anxiety, at the end of each experiment. The responses of MASI were analysed mainly with mean comparisons. The total mean score of MASI in each condition of VR1, VR2, VR3, and REAL was 58.20, 64.30, 61.37, and 67 respectively. The difference was significant at 5% level ($p = 0.002$). In particular, the difference between mean of REAL and VR1 for MASI was only significant at 5% level ($p = 0.001$). The mean of MASI in VR2 represented the highest value (64.30) among all VR conditions, and it was the closest to the mean of MASI in the REAL condition.

Figure 5.16 illustrates the total mean score of each dimension of anxiety (communication, performance, and behavioural anxiety) in MASI across all conditions. The bar chart illustrates that the mean for REAL was the highest level in each type of anxiety among all conditions. Notably, the performance anxiety induced in VR2 was almost the same mean value as in the REAL condition.




| | Communication | Performance | Behavioural |
|---|---|---|---|
| Real | 22.50 | 21.50 | 23.00 |
| VR1 | 18.30 | 19.17 | 20.27 |
| VR2 | 21.37 | 21.57 | 21.37 |
| VR3 | 19.69 | 20.38 | 20.93 |

Figure 5.16: Mean Level of MASI in Three Different Types of Anxiety

The multiple comparison analysis with Sidak shows more detailed relationships between REAL and other VR conditions. The REAL and VR1 conditions only differed at 5% significant level ($p = 0.001$).

### 5.2.4 Synthetic Results

Before determining the final result of this study, the consistency of participants' anxiety responses over all measurements was investigated. This was verified by the analysis of Pearson's rho correlation coefficient (Pearson, 1938). The following tables (Table 5.3, 5.4, 5.5, and 5.6) illustrate the value of Pearson's correlation coefficient for three different types of anxiety measures in each condition respectively. As shown in the tables, the results of Pearson's rho value were less than 0.5 in all cases, which suggests that the coherence of participants' anxiety responses observed by all measurements was not strong. However, the medium size of correlation can be perceived in VR2 (*between verbal and physiological measures*) (Table 5.4), VR3 (*between behavioural and physiological measures*) (Table 5.5), and REAL (*between verbal and physiological measures*) (Table 5.6). Thus, it can be proposed that the anxiety responses produced by participants who took a virtual job interview in VR2, VR3, and REAL conditions maintained moderate consistency across all anxiety measures.

| | Behavioural (eye-contact) | | Physiological | | Verbal | |
|---|---|---|---|---|---|---|
| | Coefficient | Sig. | Coefficient | Sig. | Coefficient | Sig. |
| Behavioural | p= 1.000 | | ** p= -0.208 | 0.000 | p= -0.007 | 0.969 |
| Physiological | **p= -0.208 | 0.000 | p= 1.000 | | **p=0.232 | 0.04 |
| Verbal | P= -0.007 | 0.969 | **p=0.232 | 0.04 | p=1.000 | |

** The difference significant at 5% level, *The difference significant at 10% level

Table 5.5: The Results of Pearson's Correlation Test in the Condition of VR1

| | Behavioural (eye-contact) | | Physiological | | Verbal | |
|---|---|---|---|---|---|---|
| | Coefficient | Sig. | Coefficient | Sig. | Coefficient | Sig. |
| Behavioural | p= 1.000 | | ** p= -0.142 | 0.023 | p= -0.167 | 0.125 |
| Physiological | ** p= -0.142 | 0.023 | p= 1.000 | | * p=0.371 | 0.061 |
| Verbal | p= -0.167 | 0.125 | * =0.371 | 0.061 | p=1.000 | |

** The difference significant at 5% level, *The difference significant at 10% level

Table 5.6: The Results of Pearson's Correlation Test in the Condition of VR2

| | Behavioural (eye-contact) | | Physiological | | Verbal | |
|---|---|---|---|---|---|---|
| | Coefficient | Sig. | Coefficient | Sig. | Coefficient | Sig. |
| Behavioural | p= 1.000 | | ** p= -0.343 | 0.000 | ** p= -0.155 | 0.041 |
| Physiological | ** p= -0.343 | 0.000 | p= 1.000 | | ** p=0.217 | 0.050 |
| Verbal | ** p= -0.155 | 0.041 | ** p=0.217 | 0.050 | p=1.000 | |

** The difference significant at 5% level, *The difference significant at 10% level

Table 5.7: The Results of Pearson's Correlation Test in the Condition of VR3

| | Behavioural (eye-contact) | | Physiological | | Verbal | |
|---|---|---|---|---|---|---|
| | Coefficient | Sig. | Coefficient | Sig. | Coefficient | Sig. |
| Behavioural | p= 1.000 | | ** p= -0.126 | 0.033 | * p= -0.186 | 0.078 |
| Physiological | ** p= -0.126 | 0.033 | p= 1.000 | | ** p=0.324 | 0.011 |
| Verbal | * p= -0.186 | 0.078 | ** p=0.324 | 0.011 | p=1.000 | |

** The difference significant at 5% level, *The difference significant at 10% level

Table 5.8: The Results of Pearson's Correlation Test in the Condition of REAL

This experimental study has investigated the levels of anxiety which could be elicited in relation to the level of graphical detail of a virtual avatar from the measures of behavioural, physiological and verbal anxiety response. Table 5.7 summarises the mean difference between all conditions and its statistical significant.

As shown in Table 5.7, it was identified that the results of VR3 and REAL conditions were not statistically different in any measurements at 5% significant level, which means the highest graphic fidelity of avatar (VR3) most successfully mimicked the levels of anxiety observed in the real situation. Moreover, even if VR2 failed to replicate the physiological anxiety of the REAL condition, there was no mean difference between VR2 and REAL in behavioural and verbal anxiety measures. In addition, the results of VR2 represented no difference to those of VR3 in any measurement. According to these results, less graphically detailed virtual avatars may be sufficient to stimulate some anxiety even if the avatar does not imitate a human in an ideal way. Based on these results, the relationship between the level of anxiety and the degree of graphic fidelity may be non-linear, but asymptotic.

| | | Behavioural Anxiety | | | | Physiological Anxiety | | | | Verbal Anxiety | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PGF | | REB | | HR-b | | SCL-b | | MASI | |
| Type(I) | Type(J) | (I-J) | Sig. | (I-J) | Sig. | (I-J) | Sig. | (I-J) | Sig. | (I-J) | Sig. |
| Real | VR1 | -1.97 | **0.045 | 0.016 | **0.042 | 2.02 | **0.000 | 1.76 | **0.005 | 8.8 | **0.001 |
| Real | VR2 | -2.87 | **0.001 | 0.002 | 0.532 | 1.24 | **0.000 | 0.77 | **0.042 | 2.7 | 0.815 |
| Real | VR3 | -1.56 | 0.150 | 0.008 | 0.340 | 1.3 | 0.094 | 0.78 | 0.051 | 5.63 | 0.094 |
| VR1 | Real | 1.97 | **0.045 | -0.016 | **0.042 | -2.02 | **0.000 | -1.76 | **0.005 | -8.8 | **0.001 |
| VR1 | VR2 | -0.9 | 0.430 | -0.014 | **0.000 | -0.78 | **0.006 | -0.99 | **0.012 | -6.1 | 0.055 |
| VR1 | VR3 | 0.41 | 0.422 | -0.008 | **0.005 | -0.72 | **0.008 | -0.98 | **0.017 | -3.17 | 0.681 |
| VR2 | Real | 2.87 | **0.001 | -0.002 | 0.532 | -1.24 | **0.000 | -0.77 | **0.042 | -2.7 | 0.815 |
| VR2 | VR1 | 0.9 | 0.430 | 0.014 | **0.000 | 0.78 | **0.007 | 0.99 | **0.012 | 6.1 | 0.055 |
| VR2 | VR3 | 1.31 | 1.000 | 0.006 | 0.416 | 0.06 | 0.069 | 0.01 | 0.989 | 2.93 | 0.751 |
| VR3 | Real | 1.56 | 0.150 | -0.008 | 0.340 | -1.3 | 0.094 | -0.78 | 0.051 | -5.63 | 0.094 |
| VR3 | VR1 | -0.41 | 0.422 | 0.008 | **0.005 | 0.72 | **0.000 | 0.98 | **0.017 | 3.17 | 0.681 |
| VR3 | VR2 | -1.31 | 1.000 | -0.006 | 0.416 | -0.06 | 0.069 | -0.01 | 0.989 | -2.93 | 0.751 |

** The difference significant at 5% level,(I-J): Mean diff. Type(I)-Type(J)

Table 5.9: The Summary of Mean Difference Across All Measurements for Anxiety Response

Furthermore, the negative reactions of interviewers were utilised as a stimulus in order to activate an increase in anxiety over the course of the virtual job interview. It was obviously noticeable that the levels of anxiety increased when interviewers reacted negatively. There was strong evidence that the mean of PGF significantly changed depending on the interviewer's reactions ($p = 0.001$). Using a pair-wise comparison procedure, the participants looked at the interviewer's face least often during the negative session (mean=20.04). This was significantly smaller ($p = 0.013$) than the PGP during neutral (mean=24.5) and positive (mean=22.4) sessions. In addition, a similar result was found in eye-blink measure; the total average of REB for the different types of interviewer reaction was 0.3622, 0.3770 and 0.3716 in neutral, negative, and positive sessions respectively. The comparison revealed strong evidence that the negative reaction differed to the neutral and positive reactions ($p < 0.05$). Although the difference between the interviewer's reaction types can be found in behavioural anxiety measures only, this could be said to show that participants were more concerned about the interviewer's negative reaction than neutral or positive reactions.

## 5.3 Discussion

This study investigated the degree of anxiety elicited in relation to the level of graphical detail of a virtual avatar among students preparing for job interviews, and compared the resulting data to a real situation. The level of anxiety was measured by a combination of behavioural and physiological measures, and subjective self-reports. In terms of the different graphic details of virtual avatars, this study supposed that the graphic fidelity correlated to the levels of anxiety by an asymptotic non-linear relationship. The factor of graphic fidelity is less important to provoke anxiety in a virtual social simulation than might have been expected. Even if the highest graphic details of the virtual interviewer came closest to mimicking the levels of anxiety observed in the real situation, an avatar at a lower level of realism (*e.g. cartoon-like avatar*) also successfully provoked the avoidance of eye-contact, as well as increased eye-blink, pulse rate, and skin-conductance responses. Additionally, participants' verbal responses showed similar effects.

In this experiment the negative reactions of virtual avatars were utilised as a stimulus to elicit an increase in anxiety over the course of the virtual job interview. It was noticed that the negative reactions stimulated higher anxiety levels than when the interviewer reacted neutrally or positively. The results suggest that participants were more concerned about the interviewer's negative reaction than neutral or positive reactions. This phenomenon was shown in Pertaub's study where participants felt more comfortable with a positive group of avatars and experienced substantial distress with an unpleasant audience in a performance-requiring virtual situation (Pertaub *et al.*, 2002). This appears to support the hypothesis that anxiety may be induced by the thought of being in a social interaction (Klinger *et al.*, 2005), although the more graphically detailed the virtual avatar was, the more it provoked anxiety.

## 5.4 Summary

This study investigated how the level of anxiety varies in response to the different graphic details of a virtual avatar in a job-interview simulation, and attempted to find out the level of graphic detail of avatar that would be required to mimic the anxiety felt by individuals attending a real interview situation. The most graphically detailed 3D human avatar was the closest to mimicking the levels of anxiety observed in the real situation, but a less graphically detailed avatar (*e.g. a cartoon-like avatar*) was also sufficient to provoke anxiety. Moreover, it was identified that a virtual avatar's negative reactions induced an increase in anxiety in the job-interview situation. This may have happened because subjects were concerned about the interviewer's negative judgments, despite the interviewer not being "*real*".

CHAPTER 6

# Social Anxiety and Immersive VR Displays

A number of past studies in the field of VR therapy have demonstrated the relationship between the level of immersion and treatment outcomes in VRET (Krijn *et al.*, 2004 and Bullinger & Riva, 2005). However, these studies were limited to height phobia only, and compared CAVE and HMD conditions which were both fully immersive environments. Due to the lack of evidence about how human anxiety varies in accordance with different immersive levels of VR environment, this study investigated the relationship between the levels of anxiety and various visual displays providing different levels of immersive VR environment.

## 6.1 Objectives of the Study

As mentioned earlier (Section 3.1.3), the objective of this study was to compare a potential user's anxiety responses in a variety of VR exposures using different immersive levels of visual display, such as high resolution of HMD including a motion tracker, 50-inch LCD TV, 14-inch laptop screen and audio only. From this comparison, the study attempted to identify the correlation between anxiety and the level of immersion, which might inform the development of VRET for social phobia.

## 6.2 Experimental Method

This section describes the detailed experimental design for this study. Experimental design issues such as apparatus and materials, the selection of participants, and measurements are concerned with extending the previous experimental studies in Chapters 4 and 5.

### 6.2.1 Virtual Social Simulation

The quality of graphics and sounds in the virtual job-interview simulation has been improved according to problems that were identified in the earlier study. The white-noise from the sound source was reduced by the technique of a dynamic noise suppressor (D/Noise 1.0d) and more key frames were added to improve the realism of the avatars and the environments. Figure 6.1 shows the virtual job-interview simulation. This was programmed and rendered using Virtools v4.0.

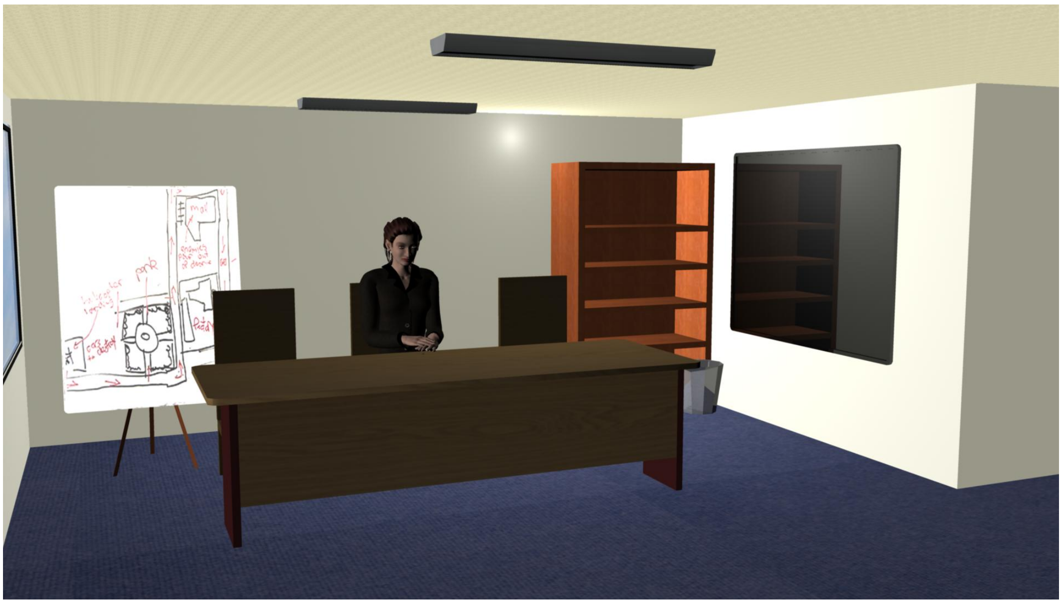


Figure 6.1: Screenshot of a Virtual Room for the Job-Interview Simulation

### 6.2.2 VR Environments

Four different forms of VR environment were developed to activate diverse levels of immersion.

***Head Mounted Display (fully-immersive display)***: A non-stereoscopic head mount display was utilised to simulate the virtual job-interview scenario. The HMD (NVIS nVisor SX) was encompassed by a head motion tracker (Polhemus 6DOF Motion Tracker) so that the point of view displayed in the monitor changed as the user moved their head. The HMD has a resolution of 1280x1240x60Hz, and run with Intel Q6600 2.4GhZ core 2 Quad processor and Nvidia Geforce 8800 GTX with 768 MB of RAM (Figure 6.2).

***Large LCD (semi-immersive display)***: In this scenario, the virtual job-interview was simulated by a 50-inch LCD TV with Intel Q6600 2.4GhZ core 2 Quad processor and Nvidia Geforce 8800 GTX with 768 MB of RAM. In order to increase the level of immersion, the VR exposure was conducted in a dark environment (Figure 6.2).

***Laptop (non-immersive display)***: The virtual job interview was delivered by the use of a 14-inch laptop (Acer Aspire 5920G) in a dark room setting. The simulation was rendered by NVIDIA Geforce 8600M GT TurboCache with 1024X800X60Hz resolution.

***Audio-only***: Participants in this condition took the virtual job-interview simulation with audio only. A typical stereo headset (SONY MDR-NC60) was used to deliver the job interview. In order to isolate participants from surroundings, they wore a blindfold.

Figure 6.2: Experiment Setting for HMD (Left) and Large LCD (Right)

### 6.2.3 Measurements

The experimental study employed three self-rate scales and two physiological instruments (Pulse Rate and Skin Conductance Response) for measuring the severity of social anxiety. Two self-rate scales were used as screening instruments: the Liebowitz Social Anxiety Scale (LSAS) and the Brief Fear of Negative Evaluation Scale (BFNE). One self-rate scale (Measure of Anxiety in Selection Interviews) and the physiological instruments were exploited to appraise the levels of anxiety during the VR exposures.

#### 6.2.3.1 Screening Instruments

LSAS was employed as a screening instrument to recruit appropriate target participants in this experiment, and BFNE was used for indicating practice or sequence effects between the first and second VR exposure, which is the typical weakness of the within-subject design.

*Brief Fear of Negative Evaluation Scale (BFNE)* - Leary (1983) developed a brief version of the fear of negative evaluation scale that is widely used to assess various dimensions of social evaluative anxiety (e.g. distress, avoidance, expectations). The tool contains 12 items with responses based on a five-point Likert metric

(*1=not at all characteristic of me; 5=extremely characteristic of me*). Total scores range from 12 to 60. This brief version of FNE correlates highly with the original scale ($r = 0.96$, Leary (1983)). The validity of the BFNE was supported through significant correlations with the Social Avoidance and Distress Scale (SAD) ((Watson & Friend, 1969) and the interaction anxiousness scale (Leary, 1983). The details of this scale were explained in Section 3.4.3.1. (Appendix A.1)

*Liebowitz Social Anxiety Scale (LSAS)* - LSAS is widely used to identify the severity of an individual's social anxiety in real life. This self-rating scale contains 24 items to measure social fear, social avoidance, performance fear, and performance avoidance. According to the scoring scale, individuals can be diagnosed as having moderate social phobia (55-65), marked social phobia (65-80), severe social phobia (80-95) and very severe social phobia (more than 95 out of a total of 144). The details of this scale were explained in Section 3.4.3.1. (Appendix A.2)

#### 6.2.3.2 Anxiety Assessments

To measure the severity of manifested tension or apprehension during the anxiety-provoking virtual job-interview simulation, two different types of assessment tool were applied in the study: verbal and physiological responses.

*Measure of Anxiety in Selection Interviews (MASI)* - MASI was developed by McCarthy & Goffin (2004) to measure job-interview anxiety in five dimensions: Communication, Appearance, Social, Performance, and Behavioural. Each aspect includes six items respectively (Total 30 items), and the items can be rated on a five-point response scale (*1=strongly disagree, to 5=strongly agree*). As some items were not applicable to this virtual job-interview simulation, the 18 most relevant items were selected to ask about aspects of communication, performance, and behavioural anxiety. The details of this scale were explained in

Section 3.4.3.2. (Appendix A.3)

*Physiological Responses* - Pulse Rate (PR) and Skin Conductance Response (SCR) were used to determine the level of anxiety. The data for PR and SCR was collected by Contact Precision Instrument's amplifier. Customised analysis software (Psylab) was applied to pre-process the data and to remove movement-related artefacts. PR was calculated by the average number of beats per minute (Equation 3.1). In the same way, the mean of skin conductivity startle response (microsiemens scores) was calculated for the period of every minute (Equation 3.2).

### 6.2.4 The Selection of Participants

Participants were recruited from the student population at the University of Warwick through the use of both online and offline advertisements (e.g. emails, online banners, and posters on notice-boards in the library and accommodation on campus)(Appendix B.2). The study advertisement was delivered to every Student Social Club and the Warwick Careers Centre also helped us to recruit the target population. When students notified us of their wish to participate in this experimental study, they were given an electronic invitation letter with the link to the study website (Appendix B.1). This included all the information about the study objective, booking a date and time for the experiment, and submission of the online Liebowitz Social Anxiety Scale (LSAS).

As a consequence of unpredictability as to how many of the target population for this experimental study may have moderate symptoms of social anxiety, a judgemental sampling method in non-statistical sampling model was used to determine a sample size (Bryman, 2001). This method is not able to draw a general role from the result in this study with the model of statistical probability

(Bekmont, 2008), however, it is useful for generating hypotheses for further studies of aspects of anxiety provoking in VR. The observations of this study were undertaken within artificially controlled and constricted environment.

The criteria of participants in this study were those who had at least moderate symptoms of social phobia, thus we only invited individuals who scored more than 55 in LSAS. Initially, 36 students wished to take part in this experiment, but 16 of these applicants were excluded because they did not match our criteria. Finally, 20 students were selected; their total average score of LSAS was 58.78 (SD=4.17). The ethnic background was 14 female and 6 male, aged between 21 and 31 years old, 16 of whom were Asian (Chinese, Korean, Indian, Thai and Japanese) and four European (Italian, Hungarian, Slovenian and Norwegian). Fourteen participants were postgraduate students and six were undergraduate students (Table 6.1). In order to increase the effect of sample size the treatments were repeated. To reduce sequence effect, the test orders and conditions were counterbalanced, thus the selected students (n=20) were divided into four groups as closely matched as possible with respect to demographic and severity of social phobia symptoms. In the second exposure, two female participants who were in the conditions of Laptop and Audio dropped out.

| Group Name | No. Subjects | Mean of Age (SD) | Gender (Female / Male) | The mean of LSAS score (SD) | Session Order | |
|---|---|---|---|---|---|---|
| | | | | | First Test | Second Test |
| A | 5 | 26.5 ( 3.05) | F=3 M=2 | 58.1 (6.67 ) | HMD | LAPTOP |
| B | 5 | 26.0 (3.41) | F=4 M=1 | 57.8 (2.14 ) | LCD | AUDIO |
| C | 5 | 27.1 (3.21) | F=3 M=2 | 57.55 (3.53 ) | LAPTOP | LCD |
| D | 5 | 24.5 (2.91) | F=4 M=1 | 58.12 (1.05) | AUDIO | HMD |
| Total | 20 | 25.95 (2.84) | F=14 M=6 | 58.78 (4.17) | | |

Table 6.1: Profile of Groups

### 6.2.5 Experiment Procedures

At the beginning of the virtual job-interview session, participants were asked to submit a consent form (Appendix B.3) for the agreement of this experimental study and a self-reported scale: Brief Fear of Negative Evaluation Scale (Appendix A.1) for identifying their trait of social anxiety. After that, they were exposed to one of the four VR environments or conditions. During the VR exposure, participants' pulse rate and skin conductance level were recorded. At the end of the virtual job interview, participants submitted Measure of Anxiety in Selection Interviews (MASI) to report their state of anxiety. One week later, they were invited for a second exposure. As with the first procedures, all participants were asked to complete the BFNE and were then exposed to the virtual job interview with a different condition of VR environment. Finally, they were asked to complete MASI again (Figure 6.3).

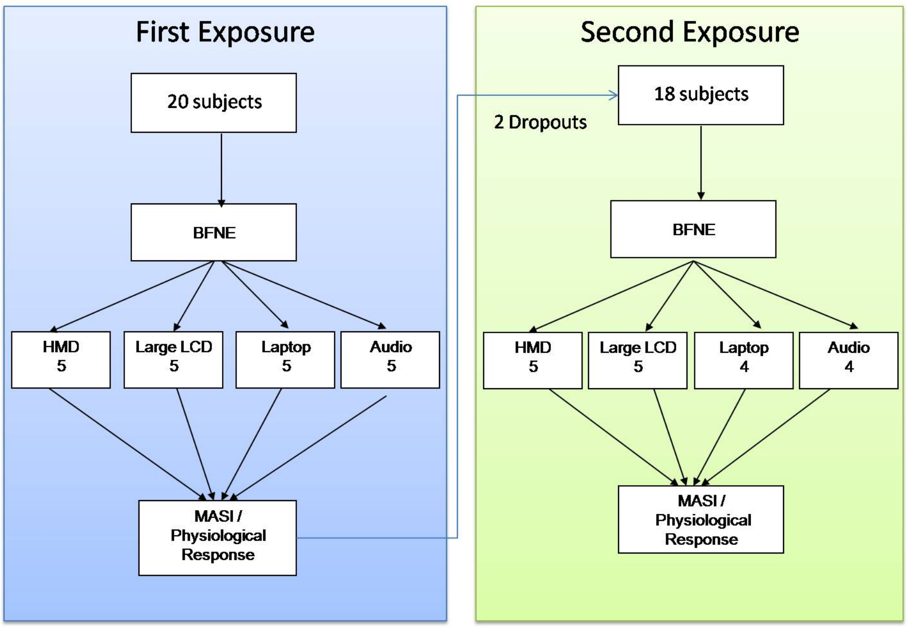



Figure 6.3: The Process of the Experiment

## 6.3 Results

This section, initially investigates the equivalency between groups, and examines carryover effects between the first and second exposure, which is an imperative process in this type of experiment design, before analysing key results. The investigation is accomplished by the comparison of the mean difference of BFNE between groups, and session orders. Secondly, the results of physiological responses and MASI are evaluated to indicate the differences between anxiety levels among the various immersive levels of VR conditions. This evaluation was conducted mainly using Analysis of Variance (ANOVA) with post-hoc procedure to test significance where two or more conditions were used.

### 6.3.1 Equivalency of Groups

The mean difference of BFNE was evaluated by ANOVA test with the intention of identifying the differentiation of the four groups. Table 6.2 describes the result of the ANOVA test which computed the mean difference of BFNE between groups and its significant levels.

| ANOVA (The first test of BFNE) | | | | | | |
|---|---|---|---|---|---|---|
| | | Sum of Squares | df | Mean Square | F | Sig. |
| BFNE-1 | Between Groups | 22.000 | 3 | 7.333 | .557 | .651 |
| | Within Groups | 210.800 | 16 | 13.175 | | |
| | Total | 232.800 | 19 | | | |
| ANOVA (The second test of BFNE) | | | | | | |
| | | Sum of Squares | df | Mean Square | F | Sig. |
| BFNE-2 | Between Groups | 4.133 | 3 | 1.378 | .081 | .969 |
| | Within Groups | 237.867 | 14 | 16.990 | | |
| | Total | 242.000 | 17 | | | |

Table 6.2: The Results of BFNE in Each Group

As can be seen from Table 6.2, the differentiation of the four groups was not significant either in the first or the second test, which shows that the participants were equally allocated into four groups without any bias. In order to investigate any sequence effects between the first and second experiment, the mean in the first submitted BFNE was compared with the mean in the second submitted BFNE. The following bar-chart (Figure 6.4) shows that the second mean score of BFNE was slightly lower in comparison to the first mean score of BFNE. However, the difference between them was not significant at 5% level ($p = 2.12$). This result shows that there was no strong evidence to criticise any practice and sequence effect between the first and second exposure, even if it shows a mean reduction in the second BFNE.

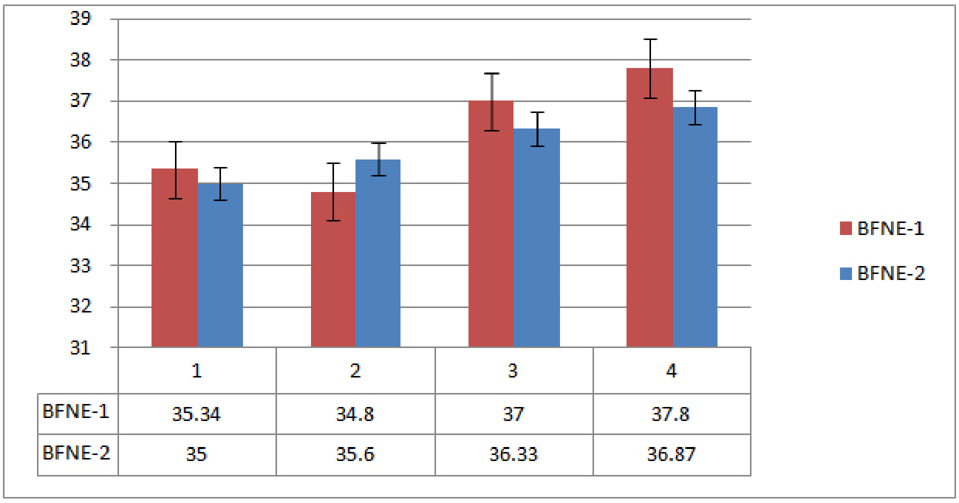


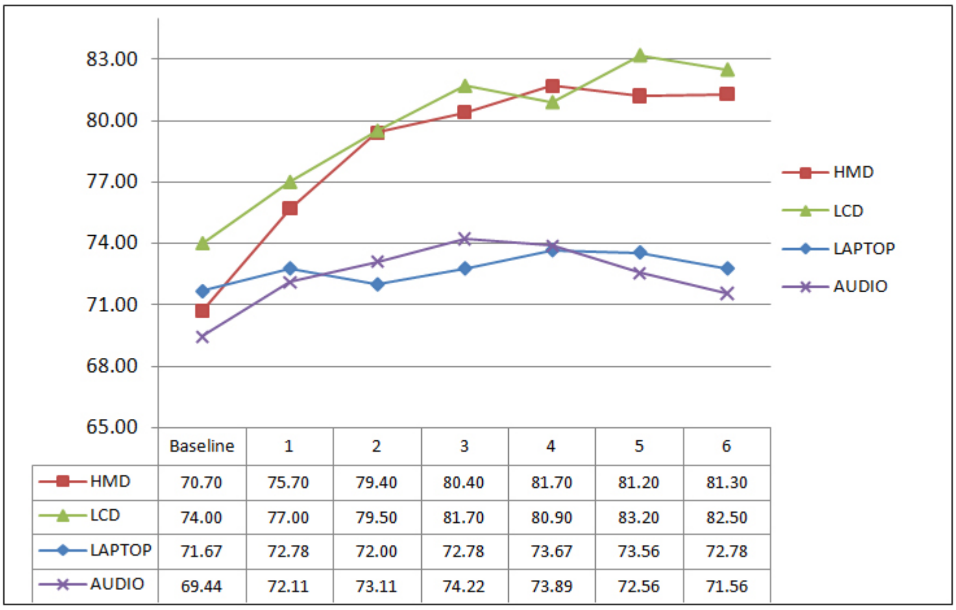

Figure 6.4: Mean of BFNE in Each Group

### 6.3.2 Comparison of Results for Anxiety Measures

Unfortunately due to an unnoticed connection problem with the electrodes a full set of data for Skin Conductance Response (SCR) in the second experiment was not recorded. Hence, only the results of Pulse Rate are presented at this time.

All participants spent approximately six to seven minutes (average = 394.6

seconds) completing the virtual job interview. The following graph shows how the pulse rate changed over the course of the virtual job interviews, up to six minutes (Figure 6.5).

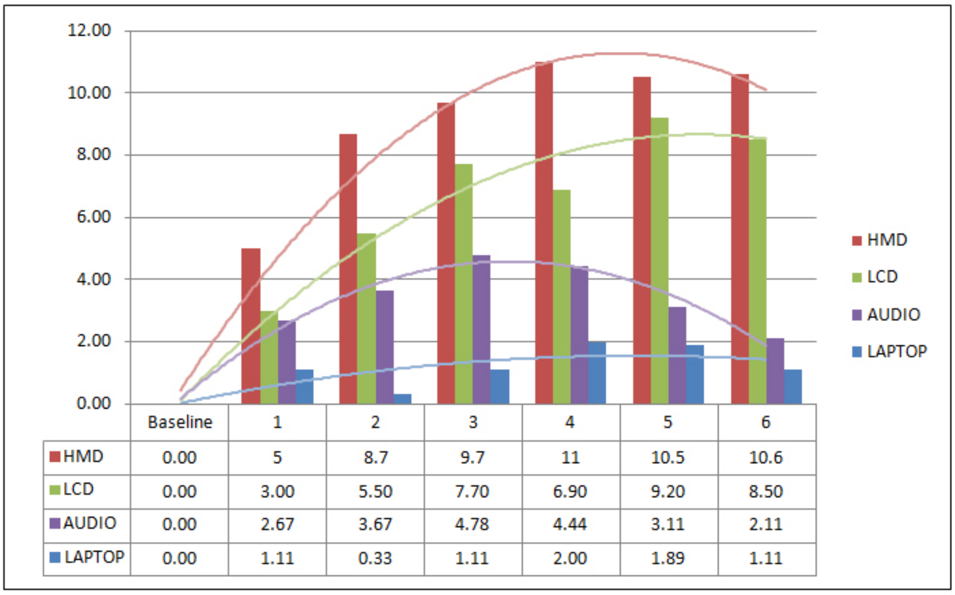



| | Baseline | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| HMD | 70.70 | 75.70 | 79.40 | 80.40 | 81.70 | 81.20 | 81.30 |
| LCD | 74.00 | 77.00 | 79.50 | 81.70 | 80.90 | 83.20 | 82.50 |
| LAPTOP | 71.67 | 72.78 | 72.00 | 72.78 | 73.67 | 73.56 | 72.78 |
| AUDIO | 69.44 | 72.11 | 73.11 | 74.22 | 73.89 | 72.56 | 71.56 |

Figure 6.5: The Outcomes of PR in Every Minute

Overall, the pulse rate (PR) slightly increased over the course of the virtual job interview. There were two different incremental patterns, each shared by two of the conditions. In the HMD and LCD conditions, the PR increased dramatically in the first two or three minutes of the virtual job interview. Then, the lines show noticeable fluctuations, with a steady increase. In the AUDIO condition, the PR also showed a small increase in the first few minutes, although the increase was not as great as in the HMD or LCD conditions. After three minutes, there was a gradual reduction in PR levels. In contrast, the LAPTOP condition illustrated an unexpected outcome where the levels of PR did not change much over the course of the virtual job interview. To compare further how much the pulse rate increased against baseline recordings, the increment of pulse rate was calculated as the mean of pulse rate minus the value of baseline recordings in every minute

(PR-b). Figure 6.6 illustrates the results.




| | Baseline | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| HMD | 0.00 | 5 | 8.7 | 9.7 | 11 | 10.5 | 10.6 |
| LCD | 0.00 | 3.00 | 5.50 | 7.70 | 6.90 | 9.20 | 8.50 |
| AUDIO | 0.00 | 2.67 | 3.67 | 4.78 | 4.44 | 3.11 | 2.11 |
| LAPTOP | 0.00 | 1.11 | 0.33 | 1.11 | 2.00 | 1.89 | 1.11 |

Figure 6.6: Mean of PR-b in Each Condition

As Figure 6.6 shows, the level of increment of PR in the first minute was similar in all conditions, but the mean distance between conditions widened later on. The total average of PR-b in HMD, LCD, AUDIO and LAPTOP conditions was 9.25, 6.80, 3.46 and 1.26 respectively. The difference of the total mean was significant between the four conditions at 5% level ($p = 0.001$). Thus, the mean difference between combinations of the four conditions was evaluated through the test of ANOVA with Sidak procedure for pair-wise multiple comparisons. As Table 6.3 shows, the difference between HMD and LCD was only insignificant at 5% levels ($p = 0.231$), which means the LCD condition induced an increase in PR as much as the HMD condition. In addition, it should be noted that the variation between LAPTOP and AUDIO was not significant at 5% levels, but it was significant at 10% levels (Table 6.3).

| Sig. | HMD | LCD | AUDIO | LAPTOP |
|---|---|---|---|---|
| HMD | | 0.231 | **0.008 | **0.001 |
| LCD | 0.231 | | **0.007 | **0.001 |
| AUDIO | **0.008 | **0.007 | | *0.065 |
| LAPTOP | **0.001 | **0.001 | *0.065 | |

** The difference significant at 5% level, *The difference significant at 10% level

Table 6.3: Multiple Comparisons with Sidak Procedure

These results suggest that even if the participants who were exposed to the virtual job interview through HMD indicated the tendency of a higher increment in pulse rate than other technical conditions, no strong evidence can be found to determine any dissimilarity between the HMD and LCD conditions. Furthermore, participants in the audio-only condition maintained a greater increment of PR than the group who were exposed to the virtual job interview through a laptop screen. However, the difference in the total average of PR increment between the two treatments was not large.

In order to identify whether similar results to the physiological responses were shown in the participants' verbal reports, the results of MASI were analysed.

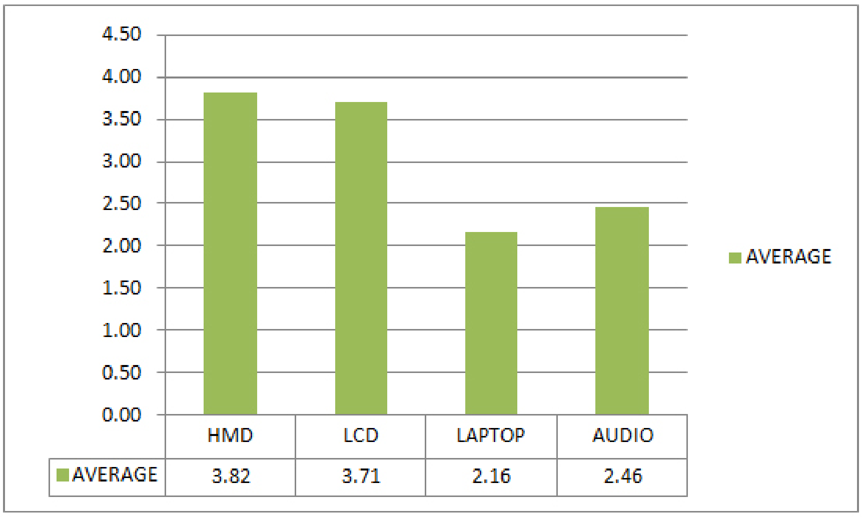
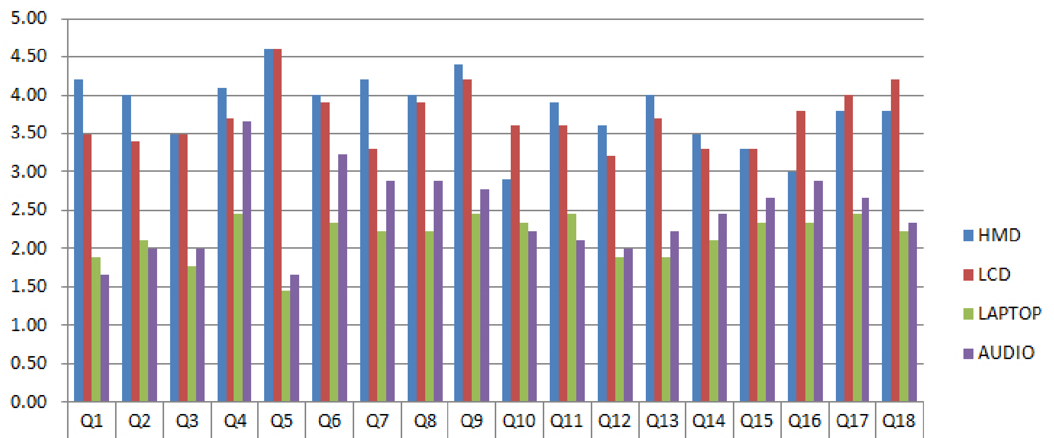



Figure 6.7: Total Mean of MASI in Each Condition

The overall mean of the response to MASI in each condition of HMD, LCD, LAPTOP, and AUDIO was 3.82, 3.71, 2.16, and 2.46 respectively (Figure 6.7). HMD and LCD conditions showed the highest levels in total mean of MASI. In contrast, the LAPTOP condition showed the lowest mean level in this measurement.

In order to demonstrate these tendencies by statistical investigation, ANOVA was conducted with Sidak procedure for pair-wise comparison between conditions. The difference of total mean in MASI among the four conditions was significant at 5% levels ($F(3, 34) = 281.98, P < 0.001$). From the multiple comparison procedure it was noticed that in the HMD and LCD conditions the total mean of MASI did not vary at 5% significant level ($p = 0.485$). This result indicated that, overall, the condition of the large LCD screen provoked a similar level of anxiety to the HMD condition.

The mean of responses in each item for MASI within the four conditions are illustrated in Figure 6.8.




| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HMD | 4.20 | 4.00 | 3.50 | 4.10 | 4.60 | 4.00 | 4.20 | 4.00 | 4.40 | 2.90 | 3.90 | 3.60 | 4.00 | 3.50 | 3.30 | 3.00 | 3.80 | 3.80 |
| LCD | 3.50 | 3.40 | 3.50 | 3.70 | 4.60 | 3.90 | 3.30 | 3.90 | 4.20 | 3.60 | 3.60 | 3.20 | 3.70 | 3.30 | 3.30 | 3.80 | 4.00 | 4.20 |
| LAPTOP | 1.89 | 2.11 | 1.78 | 2.44 | 1.44 | 2.33 | 2.22 | 2.22 | 2.44 | 2.33 | 2.44 | 1.89 | 1.89 | 2.11 | 2.33 | 2.33 | 2.44 | 2.22 |
| AUDIO | 1.67 | 2.00 | 2.00 | 3.67 | 1.67 | 3.22 | 2.89 | 2.89 | 2.78 | 2.22 | 2.11 | 2.00 | 2.22 | 2.44 | 2.67 | 2.89 | 2.67 | 2.33 |

Figure 6.8: Mean of MASI in Every Item

As shown in Figure 6.8, the HMD condition mostly showed the highest mean value in each item of MASI, although the mean level was sometimes lower than for the LCD condition. The LAPTOP condition indicated the lowest mean level in each item. This was unexpected, given our initial assumption that the low immersive levels of VR environment in the audio-only condition would induce the lowest mean level in each item.

The mean difference within conditions in each item was analysed with a generic ANOVA test including post-hoc procedure. It was confirmed that the mean of each item in every condition was significantly different at 5% level ($p < 0.05$) excepting *Q15. My heartbeat was faster than usual during job interviews*. From the comparison of the mean level in each item with combinations of the four conditions, there was no mean difference in almost all cases between HMD and LCD, or between LAPTOP and AUDIO conditions. This noticeable fact shows that participants who took the job interview with a large size of LCD screen felt as much anxiety as the participants in the HMD condition. In addition, it can be identified that the audio-only condition was able to provoke the feeling of anxiety to some degree, and that the level of anxiety was similar to the participants who were exposed to the virtual job-interview simulation through a laptop screen.

From the results of this comparison, it was confirmed that the same results in both verbal and physiological measures were observed in this experiment. The levels of anxiety were shown to be highest in the HMD and LCD conditions, followed by AUDIO and LAPTOP.

### 6.3.3 The Responses to Three Different Types of Anxiety

In order to identify the participants' specific anxiety levels for three different aspects - communication, performance, and behavioural anxiety -the mean levels of MASI were compared in each. The following graph illustrates the mean levels of MASI for each type of anxiety (Figure 6.9).

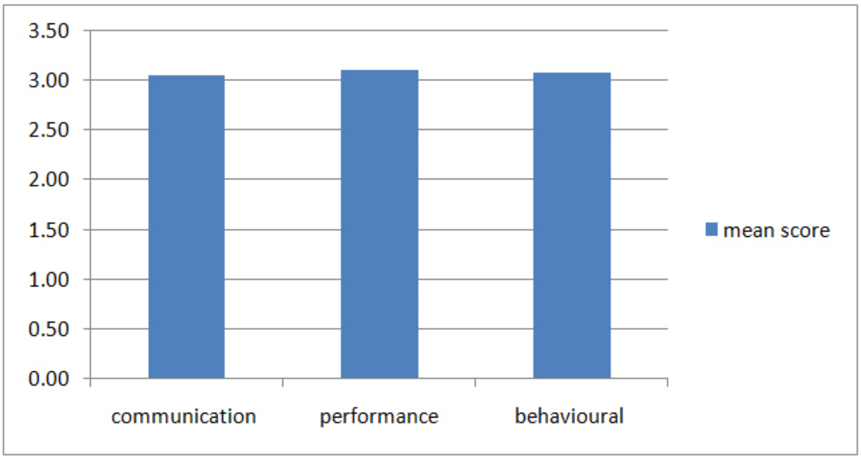



Figure 6.9: Total Mean Levels in Each Factor of MASI

The average for communication, performance and behavioural anxiety was 3.05, 3.10, and 3.07 respectively. According to the graph, performance anxiety was slightly higher than the other factors, but no difference can be found among all factors at 5% significant level ($p = 0.932$).

Furthermore, to ensure how strong the three different types of anxiety are correlated each other, the Pearson's correlation analysis was conducted between the combinations of each factor (Table 6.4).

| Correlations | | | | |
|---|---|---|---|---|
| | | Communication | Performance | Behavioural |
| Communication | Pearson Correlation | 1 | **0.902 | **0.736 |
| | Sig. (2-tailed) | | 0.000 | 0.000 |
| | N | 38 | 38 | 38 |
| Performance | Pearson Correlation | **0.902 | 1 | **0.797 |
| | Sig. (2-tailed) | 0.000 | | 0.000 |
| | N | 38 | 38 | 38 |
| Behavioural | Pearson Correlation | **0.736 | **0.797 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | |
| | N | 38 | 38 | 38 |

** The difference significant at 5% level

Table 6.4: The Levels of Correlation Coefficient within Three Aspects of Anxiety

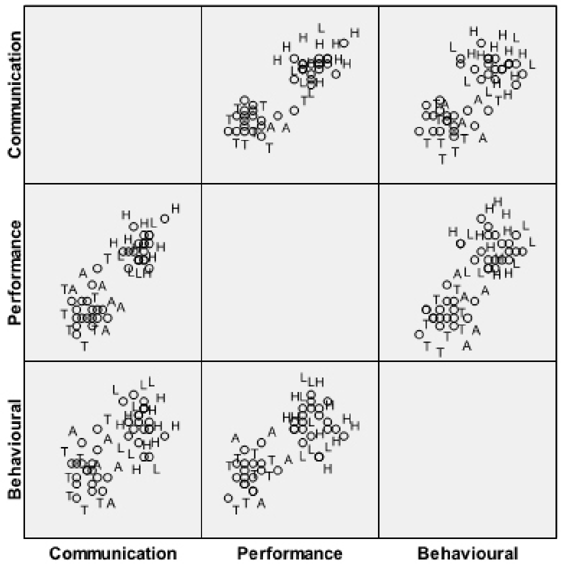
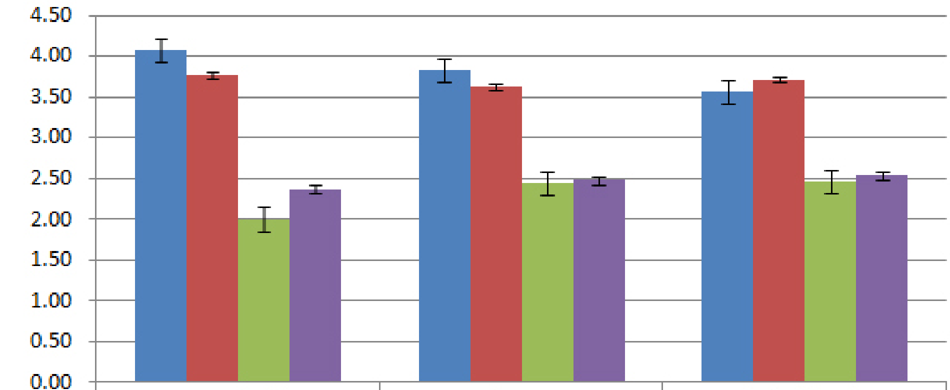



Figure 6.10: The Scatter Plots of the Combinations of Three Different Types of Anxiety

As shown in the results of Table 6.4, the correlation was significant in each of the factors. The most correlating factors were communication and performance ($\rho = 0.902$). These two factors have a strong positive coefficient. This shows that when participants felt a high level of communication anxiety, they also suffered a high level of performance anxiety. Behavioural anxiety was less correlated to the other two factors (Table 6.4 and Figure 6.10). This indicated that even if participants felt a high level of communication and performance anxiety, they reported that no strong behavioural symptoms were experienced, such as an increase in heart rate, sweating, dry mouth, or hands shaking. However, it was indicated that their actual level of pulse rate was higher than they thought based on their behavioural symptoms ($\rho = 0.037$). In order to investigate how this result varies in accordance with the four different conditions of VR environment, the mean levels of MASI were compared in each type of anxiety in the different conditions. Figure 6.11 illustrates the mean levels of MASI in each type of anxiety respectively.




| | communication | performance | behavioural |
|---|---|---|---|
| HMD | 4.07 | 3.83 | 3.57 |
| LCD | 3.77 | 3.63 | 3.72 |
| LAPTOP | 2.00 | 2.44 | 2.46 |
| AUDIO | 2.37 | 2.48 | 2.54 |

Figure 6.11: Mean Levels of Three Types of Anxiety in MASI in Four Conditions of VE

The HMD and LCD conditions were shown to have higher mean levels than the other two conditions (LCD and AUDIO) for every type of anxiety. The difference for each of them was significant at 5% levels ($p < 0.005$). In a correlation test with Pearson's procedure, the HMD, LCD, and LAPTOP conditions showed similar results to the previous correlation test (Table 6.4). However, in the AUDIO condition, there was a very low coefficient between behavioural and performance anxiety ($\rho = 0.087$). The reason could be that the participants in the audio-only condition were not concerned about their performance in the job interview, and thus did not feel any anxiety in the aspect of performance.

## 6.4 Discussion

From the results of this experiment, this study confirmed that an increase in pulse rate appeared in all conditions to some degree: HMD (fully-immersive environment), LCD (semi-immersive environment), LAPTOP (non-immersive environment), and AUDIO (audio only). In particular, the HMD and LCD conditions represented comparable levels of increase in pulse rate, and showed the highest anxiety levels amongst all conditions. In addition, the LAPTOP and AUDIO conditions indicated similar levels of anxiety in terms of the results for pulse rate. This consequence can also be found from the results of participants' verbal response.

The audio-only condition showed an unpredictable increase in anxiety which was much higher than the LAPTOP condition. This phenomenon could be explained by the theory of auditory mental imagery (Kosslyn *et al.*, 1995). Auditory mental imagery is 'hearing' in the absence of appropriate visual input and is grounded on the concept of mental imagery. The mental image is generally viewed as being generated internally without adequate external stimulus. Thus, it is possible that the audio-only condition, even without visual input, may increase the sense of presence together with a corresponding increase of anxiety. However, this assumption should be investigated further.

Due to the complexity of anxiety measurements, this experiment used two diverse types of anxiety measurement: a self-reporting questionnaire (MASI) and physiological assessment tool (pulse rate). These anxiety measurements had different features although both had the ability to collect a variety of responses from participants. MASI made it possible to obtain each participant's subjective anxiety experience during the job interview. The physiological assessment device captured a participant's somatic symptoms of anxiety. In addition, the correlation between two measurements was significant at 5% level ($p = 0.526, p = 0.001$). Thus, both anxiety measurements were able to determine the level of anxiety for this experiment study. However, even though those measurements represented great benefits in recognising a participant's level of anxiety during the job interview, caution is needed as this does not necessarily provides conclusive proof of the actual level of anxiety.

The findings in this experimental study suggest a means for the development of effective VRET for social phobia. A diversity of visual displays may be a potential approach to treatment, providing anxiety-provoking stimuli in a gradual order.

## 6.5 Summary

The aim of this study was to identify how the level of anxiety produced by a virtual job-interview simulation varied in accordance with four different levels of immersive visual display. The initial hypothesis in this study was that the higher immersive levels of visual display might provoke higher levels of anxiety. The relationship should be orthogonal. However, this experiment proved that this assumption was not entirely valid.

The study confirmed that participants who have symptoms of social phobia felt similar levels of anxiety in both fully and semi-immersive levels of visual display, which means they were concerned more about the source and context of anxiety than the quality of immersion. However, in order to activate anxiety and maintain it over the course of the virtual simulation, a minimal level of immersive display is required.

CHAPTER 7

# Thesis Discussion

This thesis aimed to make a significant contribution towards a deeper understanding of the role of perceptual presence factors in provoking anxiety in VR therapy for social phobia. Chapters 4, 5 and 6 presented experimental studies investigating, respectively, how well the virtual social simulation fits the needs of the psychological approach, how the individual's anxiety varies in relation to different graphic fidelity of avatars in a social-anxiety-stimulating virtual simulation, and how the visual displays for VR influence the activation of anxiety in the virtual social simulation. This chapter summarises the main findings of those experiment studies, and discusses several issues related to the potential impact from the results of this research.

## 7.1 Summary of Main Findings

The use of VR as a fear-provoking system is based on its characteristic of perceptual illusion: *the sense of presence*. This VR experience can progressively immerse individuals in a specific feared situation, and enables users to revisit the situation without any public embarrassment and its inaccessibility. Thus, one key condition of performing an efficient VR exposure therapy is to provoke similar feelings of anxiety as those that would be felt in a real situation. This research has proposed a high fidelity virtual reality simulation in order to activate a significant degree of anxiety. Our results show the potential of virtual reality in the use of therapeutic and diagnostic interventions for job-interview fear. Moreover, the relationship between perceptual presence factors of virtual environment and degree of human anxiety has been clearly demonstrated.

### 7.1.1 Anxiety-Provoking Virtual Job-Interview Simulation

The virtual simulation that was developed progressively immersed individuals in the mock job-interview scenario. In the virtual simulation, participants responded to virtual interviewers much as they would to real interviewers, and often experienced considerable stress, despite recognising the artificiality of the situation. Anxiety-related symptoms from participants could be observed over the course of the job-interview. Most participants felt that it was difficult to make eye-contact with negatively reacting virtual interviewers. It seems that the eye-contact and blink behaviours were an important non-verbal sign for measuring some degree of anxiety. Even though the virtual simulation had several technical limitations, the system was well suited to the needs of the psychological approach which was used for main experiment studies.

### 7.1.2 Visual Reality of Avatar and the Degree of Anxiety

The study in Chapter 5 investigated the relationship between anxiety levels and graphical fidelity of avatars in a virtual social simulation in order to identify the impact of graphical fidelity of virtual avatars. The study measured the degree of anxiety elicited by various degrees of graphical details of virtual avatars among students preparing for a job-interview, and compared their responses to a real situation. The findings indicated that the highest graphic detail of the virtual avatar came closest to mimicking the levels of anxiety observed in the real situation. In measures of behavioural, physiological, and verbal anxiety, there was statistically no mean difference between the condition of highly realistic avatar and real interviewer. However, an interesting result indicated that an avatar at a lower level of realism (*e.g. a cartoon-like avatar*) also successfully provoked a significant degree of anxiety, similar to the level observed in the real situation. Even if the cartoon-like avatar failed to replicate the physiological anxiety of the real condition, the results in behavioural and verbal anxiety measures represented no difference to those of the real condition, and also no strong evidence could be found to criticise any graphical effects between the highest graphic levels of avatar and the cartoon-like avatar. According to these results, less graphically detailed virtual avatars may be sufficient to stimulate some anxiety even if the avatar does not imitate a human in an ideal way. This appeared to support the hypothesis that anxiety may be induced more by the thought of being in a stressful situation than by the graphical realism of the virtual avatar.

Various types of virtual avatar have been developed in previous studies. All studies successfully provoked a significant degree of anxiety, even at lower levels of graphical details. For example, Pertaub *et al.* (2002) have immersed phobics in a virtual public speaking situation with cartoon-like avatars. The study concluded that participants responded to virtual avatars as real listeners, which provoked significant levels of distress. In addition, James *et al.* (2003) exposed individuals to various virtual social situations and found anxiety was provoked when participants interacted with virtual humans who appeared cartoon-like and reacted in an unfriendly way. Even with these unrealistic graphical details of avatars, participants in both studies reported significant increases in anxiety. The results of these two studies support our finding that less graphically detailed virtual avatars could stimulate a significant degree of anxiety, even if the avatar does not mimic the appearance of a real human.

Taken together, the results of this study show that more visual details of avatar provoke a greater degree of anxiety in VRET. The results may also suggest that with a medium level of realism, a virtual avatar could be enough to use as a social actor for the objective of activating anxiety. The relationship between the factor of visual realism and the degree of anxiety is illustrated in figure 7.1.

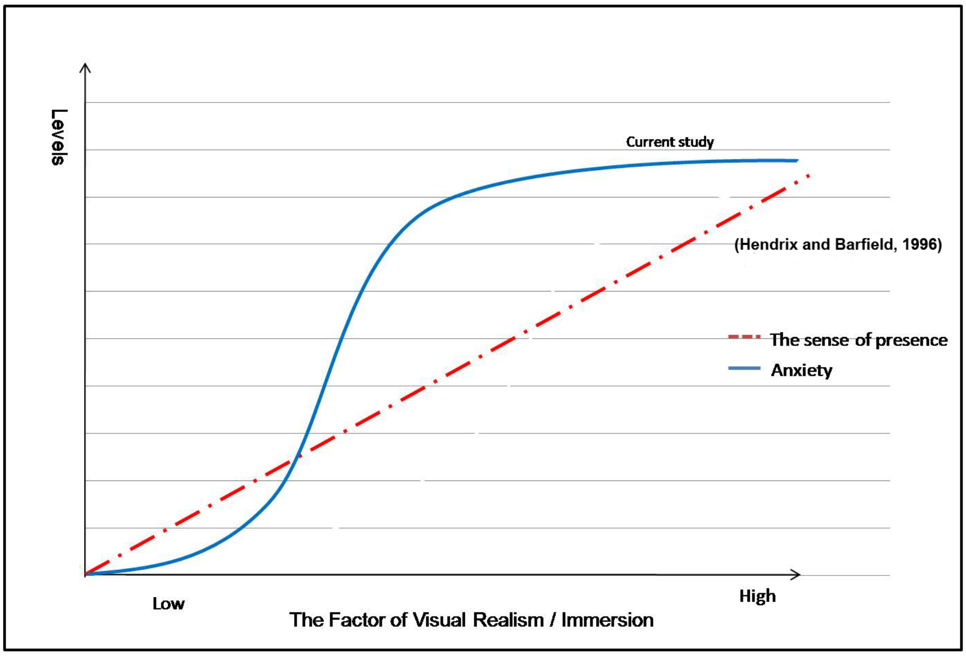



Figure 7.1: A Hypothetical Representation of Human Anxiety in VRET and Visual Realism or Immersion (Hendrix & Barfield, 1996)

Figure 7.1 describes a hypothetical representation of human anxiety in VRET. As the figure shows, the severity of anxiety is not strongly affected by the degree of visual realism in VRET, while anxiety and visual realism are correlated by an asymptotic relationship. In other words, the aspect of visual fidelity could be influenced by the thought of participants to the context of the situation. This phenomenon can be explained by mental representations induced in the participants by the thought of being involved in a potentially social interaction. The mental representation can be figured from a number of sources, such as long-term memory (*e.g. memory of their performance from past experienced job-interview*), present occurrence (*e.g. somatic symptoms such as increased eye-blink, heart rate, and sweating*), and external signs (*e.g. negative reactions from the interviewer when giving answers to the job-interview questions*). At the level of cognitive processes, the participants may internally struggle with negative assumptions about the context of the social situation, and begin to observe themselves or to monitor the sensations. These internal processes automatically provoke the somatic and cognitive symptoms of anxiety. Even if the present study was not entirely focused on verifying this assumption, the facts outlined in Chapters 4 and 5 offer some evidence to support this phenomenon. For example, participants who had some experience of job-interviews were often sensitive to the avatar's verbal responses and attitude. In addition, an increase in the feeling of anxiety appeared when participants thought the virtual avatar responded in a negative way. These facts support the assumption that the participant tends to be concerned about other's responses and the situation. To make this assumption clearer, it could be necessary for further research to investigate the potential effects of mental representations in terms of provoking anxiety during the course of VR exposure through a cognitive approach.

### 7.1.3 Visual Reality Displays and the Degree of Anxiety

The other experimental study in this thesis compared a potential user's anxiety responses in a variety of VR environments using different immersive levels of visual display. The concept of immersion in VR has been regarded as a physical configuration of the user interfaces in the virtual reality environment, in particular the extent to which the visual displays were extensive, surrounding and conveyed a vivid illusion of reality to the participant (Slater & Wilbur, 1997). Immersive

VR is often classified into fully immersive, semi-immersive, and non-immersive (Kalawsky, 1996). This classification depends on how much the individual can perceive the VR as a real world.

A number of past studies in the field of VR have demonstrated the relationship between the level of immersion and the sense of presence. However, there are only a few studies in relation to the factor of immersion in anxiety-activating virtual environments (Krijn *et al.*, 2004 and Bullinger & Riva, 2005). The studies that investigated the relationship between the level of immersion and treatment outcomes in VRET were limited to height phobia only, and compared CAVE and HMD conditions, which were both fully immersive environments. Due to the lack of evidence about how human anxiety varies in accordance with different immersive levels of VR environment, this study developed four different levels of immersive virtual environment: high resolution of HMD for fully-immersive VR environment; 50-inch LCD TV for semi-immersive VR environment; laptop for non-immersive VR environment; and Audio only. The influence of virtual displays and its correlation to the level of human anxiety were evaluated.

The results of this study showed that the level of increment of physiological responses in the first minute was similar in all conditions, but the mean distance between conditions widened later on. The participants who were exposed to the virtual job-interview through the fully-immersive environment (HMD) indicated the tendency of a higher level of physiological response than the other conditions. Moreover, participants in the semi-immersive environment (LCD) also maintained a greater degree of physiological response than the group who were exposed to the virtual job-interview through a laptop screen or a headset only. The total average of physiological responses for the conditions of HMD and LCD was not different in statistical results. The findings from verbal measure also showed the same results as physiological responses. In the results of verbal measure, the degrees of anxiety were shown to be highest in the HMD and LCD conditions, followed by Audio and Laptop.

Overall, the result of this experimental study noticed that participants who had symptoms of social phobia felt similar levels of anxiety in both fully (HMD) and semi-immersive (large LCD screen) levels of virtual reality environment. This could suggest that some level of immersion is necessary to activate anxiety. However, the highest level of immersion (HMD) might not enhance the anxiety experienced and thus may not lead to a better emotional response. This result could be influenced by the sensitivity of participants to the environment. In particular, participants who had symptoms of social phobia were almost too sensitive to certain stimuli that others ignored, and this served to reinforce and perhaps aggravate their anxiety. Thus, although better equipment can provide an environment with a higher level of immersion, the natural tendency of avoidance can be observed in any immersive condition. However, it can be confirmed that at least some degree of physical immersion is needed to maintain anxiety levels over the course of the exposure.

The limitations of this study appeared to be that the sense of anxiety could be influenced by participants' preferences or by assessment constraints. As discussed in Section 2.2.3.2, the HMD still faces a number of challenges in relation to user variability in human factors such as the field of view, resolution, and weight of device. For example, none of the participants in this study had experienced HMD equipment previously, and some of them complained about the weight of HMD and the feeling of stuffiness. These factors may have had an impact on the expected effects for HMD in terms of provoking anxiety. Moreover, the HMD condition was not able to obtain data for gaze-avoidance behaviours because of the feature of HMD providing a very isolated environment and displaying different views according to the user's head movements. These features limited the assessment of a participant's non-verbal responses in relation to eye contact. Therefore, a further future study is required to investigate how the human factors in HMD influence the degree of anxiety.

### 7.1.4 Synthesis

The aspect of realism was a key concept to address in this research. As discussed in Chapter 2, the term "*realism*" in VR was defined by two hypothetical representations: the sense of presence and immersion. These sensations lead users to feel the illusion of being a participant in a computer world as a realistic environment. In order to investigate the impact of realism in virtual environments on anxiety response, which is the main aim of this research, the aspect of graphical fidelity and the distraction of displays were chosen among all possible factors that could relate to a sense of reality. The common finding of all the studies in this thesis was that the level of realism is one of the important factors in provoking an anxiety response similar to those that would be found in a real situation; however, the aspect of realism can be changed by the user's sensitivity and potential fear of the content of the situation. This psychological impact of the content itself seems to be at the core of the fear-relevant imagery process. The factors (*e.g. VR displays and graphical fidelity*) can be ignored only if the content is sufficient to evoke emotions in an effective way. A job-interview situation has been used in this thesis to produce an anxiety-provoking atmosphere. A job-interview is not only a highly evaluative and competitive situation, but is also not within the participant's control (Jones & Pinkney, 1989). Due to this strongly emotional situation, all participants in this research showed at least some degree of anxiety even for the lowest levels of realism. This could be why previous studies could provoke significant levels of anxiety using their VR environment even though the fidelity of each VR was different.

Nevertheless, this research confirmed that the realism was a necessary factor in VRET to provoke the anxiety responses. In particular, the realism of the virtual environment was related to the anxiety response being sustained, rather than to its initiation. For example, the results in Chapters 5 and 6 showed that the level of increment of non-verbal and physiological responses in the first few minutes was similar in all conditions, but the mean distance between conditions widened later on, and the condition with the highest fidelity preserved the increment of anxiety response longer than other conditions. In addition, the tendency of changes in anxiety responses for the high level of realism most closely replicated those in the real situation, although the overall average of anxiety level for each measure was similar for medium and high realism.

In short, the initiation of anxiety can be affected by the user's sensitivity and the degree of concern with the context of the situation. However, there is an essential need for appropriate realism of the stimuli to maintain the state of anxiety over the course of VR exposure.

## 7.2 Limitations of This Research

This research introduced an anxiety-activating virtual social simulation which might be used as a cyber-therapy for social anxiety disorder. We worked with a training and careers consultant (*Dr. Jenny O'Reilly at Warwick Careers Centre*) to develop and setup the system. However it is necessary to collaborate with clinical psychologists in future development of the virtual simulation if the system would be used in clinical settings. Due to the objectives of this research, our system was only designed to adequately deal with experimental studies. Hence, further study might be needed to research the system's usability in terms of end users in clinical practices.

Concerning the technical limitations, even state-of-the art animations of virtual humans in real time are still poor imitations of real human beings. We spent additional time to design the natural animations of avatars, however the computer available for this work was not powerful enough to present detailed human motions in real-time. For instance, the simulation often showed several polygon distortions when the avatar moves micro parts such as eyes, mouse, fingers, and hairs. Although these unexpected occurrences were not very noticeable in avatar animations, it could have influenced the sense of presence among the sensitive users. The potential effects of behavioural reality of avatars on results of this research are discussed in following section 7.3. The capacity of real-time rendering in applications for VR inhabited simulations is likely to improve with future computer performance improvements.

There were several limitations in the selection of participant. In the settings of the experiments, we used screening methods to identify appropriate participants among the University population due to the difficulty of accessing actual socially phobic patients. The participants in our recruitment did not show obvious differences in terms of the severity of their social anxiety symptoms. However, it is true that the individual differences may have an affect on the sensitivity of anxiety responses. Thus, a minimum knowledge of a participant's history and background may be helpful to estimate the expected reactions before determining the levels of anxiety. Furthermore, future research needs to investigate with larger size of samples in order to draw more general conclusions from the results.

In terms of interpretation of anxiety level, several limitations can be noticed, for instance the validity of participants' subjective responses, individual difference of physiological reactions, and the interpretation of behavioural avoidances. The detailed discussion about these issues will be presented in section 7.4. It is generally very difficult to determine precise levels of anxiety because of the anxiety mood being associated with various factors such as nervous-system activation, cognitive processing changes and behavioural tendencies. This research was only observed the increase/decrease of physiological levels compared to baseline recordings and behavioural changes during the session of VR exposure in order to determine the level of anxiety. Hence this research is limited in understanding anxiety from a cognitive perspective when they are exposed to a VR environment.

Possible limitations of this research have been broadly listed in this section. The more issues related to the animations of virtual humans and the measure of anxiety are discussed in more detail below.

## 7.3 The Potential Effects of Behavioural Realism of Avatar

This thesis proposed a high fidelity of virtual avatar to mimic a real job-interviewer. For the appearance of the avatars, we put more design time into the detail of the avatar's skin (*e.g. geometry and textures*). In addition to its animations, the virtual avatar was articulated using figures that were modelled with various 3D animating techniques such as inverse kinematics, key-framing, and blend-shaping. To simulate lifelike attitudes and gestures, the 3D human models were programmed with diverse animated behavioural expressions that would be associated with real voice recorded sound clips. They could move lips and blink eyes naturally, and express negative or positive reactions such as smiling, nodding, head-shaking, yawning, turning away, avoiding eye contact and so on (Section 3.3.2). Although the main objective of this experimental study was not related to the behavioural fidelity of the avatar, we were able to notice that these behavioural reactions of the avatar influenced the self-evaluation of an individual's performance, and thus provoked some degree of anxiety.

A number of studies have investigated the impact of the behavioural realism of an avatar on the quality of presence. Bailenson *et al.* (2002) demonstrated that more detailed human animations of avatars provoked greater levels of presence. They compared three different conditions of avatar in terms of its behaviours: low behaviour (*audio only*), medium behaviour (*avatar with voice, but limited animations*) and high behaviour (*eye-blink and lip-synchronisation*). The condition of high behaviour led participants to feel both enjoyment and co-presence, and improved their task performance. Marcos *et al.* (2009) designed a high quality of facial animating avatar which was modelled with lip-synchronisation and face-tracking technology. Users' experience was compared between cartoonish and the high fidelity of human face avatar. The human face avatar resulted in superior user understanding of the displayed avatar emotions. Furthermore, Garau *et al.* (2003) studied the role of eye gaze in virtual avatars who were representing people engaged in conversation. They compared two conditions: random-gaze and informed-gaze behaviours. The condition of informed-gaze provided a marked improvement on the quality of presence, even though the appearance of the avatar was less realistic. They also suggested that behavioural realism was a more imperative element than appearance in several face-to-face scenarios. This previous literatures dealt with the concept of co-presence. The co-presence was provoked when a virtual agent behaved like an actual human being. In particular, accurate reactions led people to have a more natural tendency to treat a virtual avatar as a social actor rather than as a mere image.

In relation to the activation of anxiety, no previous study has investigated the effects of an avatar's behavioural details. However, the impact can be assumed from the following two studies. Pertaub *et al.* (2002) used two groups of avatars for their experimental study. One continuously exhibited small twitching movements, blinking and shifting about in their chairs. The other group of avatars were not animated at all but were a static 3D image. The general finding of this study was that anxious participants experienced considerable discomfort with the unpleasantly behaving avatars. In the case of static avatars, all participants treated the avatars as a mere image and never felt any fear or nervousness. Furthermore, Muhlberger *et al.* (2008) tested the impact of an avatar's facial expressions (*happy and angry*) with socially anxious participants. The facial animations were rendered by the Cortona VRML renderer. The result indicated that all participants were able to distinguish happy and angry expressions. In particular, anxious participants avoided the attentions from the angry avatar face. Furthermore, the study in this thesis showed evidence to support the potential effects of behavioural fidelity in terms of provoking anxiety. Most participants tend to be concerned about the avatar's responses in terms of evaluation. In the measurements of eye-contact tendency, the participants showed more avoidance from the negatively animated virtual avatar. In addition, the static photo-textured avatar, which had limited emotional expressions in real-time, provoked low levels of anxiety. The above studies show the importance of non-verbal interaction in activating individuals' fear memory structure. It seems that avatars' behaviours and facial expressions are strongly correlated with the activation of anxiety.

Together with previous discussion, it can be assumed that the details of avatar animations, such as lip-synchronisation, informed gaze movement, and appropriate timing of reactions, influenced the sense of co-presence, and thus anxiety could be related to the behavioural fidelity of the avatar. Further investigation is required to identify the actual impact of behavioural fidelity of avatar on the activation of anxiety together with the psychological state of socially anxious participants.

## 7.4 The Issues of Measuring Anxiety

The present thesis used three different types of measure - verbal, behavioural, and physiological responses - in order to determine the severity of anxious mood during the virtual job-interview. There are several controversial issues in relation to the measurement of the state of anxiety.

Firstly, there is a potential effect when obtaining participants' tendency of anxiety responses to avatar reactions. The avatar delivered various reactions corresponding to participants' answers. In particular, we sometimes interrupted participants' answers if these answers were too long, using the avatar's breaking-off expression with an animation and a voice sound (*e.g. Thanks for your answer. I am going to go to the next question*). This interruption maybe had an influence in terms of increasing their anxious mood during the course of the virtual job-interview. In order to notice this potential effect, we monitored the physiological signals in real-time and tried to restrain the breaking-off animation of the avatar over the job-interview if possible. Moreover, we repeated each condition three times in a row (*e.g. negative reactions for three questions, natural reactions for three questions and positive reactions for three questions*), and calculated the average of participants' responses within the conditions. These approaches do not completely eliminate the potential impact regarding the breaking-off animation and anxiety; however, we believe that they allowed us to deal with both issues in relation to the equivalence of observation time in each participant and to obtain their natural tendency of anxiety responses during the VR exposure.

Secondly, a bio-amplifier was used to collect physiological data, which enabled reliable measurements of the activation of anxiety to be obtained. However, the interpretation of an individual's anxiety state from the results of physiological responses is limited as a consequence of wide variations in pulse-rate and skin conductance responses between individuals. In addition, there are many other reasons for having a high pulse rate, including recent exercise, consumption of a heavy meal, and adverse effects of certain drugs. Hence, this research only observed the increment of physiological responses from the normal state (*Baseline*) in order to evaluate the degree of anxiety. The mean of baseline recordings of pulse rate and skin conductance response was measured when participants were listening to calm music. Although this method enabled us to avoid the risk of invalid assumptions of a participant's state of anxiety, the value of the pulse rate is often related to other emotional moods (*e.g. the state of being excited*). Therefore, we included multiple measurements to distinguish anxiety from other emotional states, and also the consistency of a participant's anxiety responses over all measurements was evaluated.

For rating scales, it is common for some participants always to agree or disagree with the questions asked, and some participants will avoid extreme responses while others avoid responses from the middle. In order to reduce the potential bias in self-rating scales, this research conducted an investigation of the consistency of anxiety responses over all measurements using a correlation co-efficient analysis. It is true that this approach is not an ideal method for eliminating the fundamental weakness of self-rating scales; however, it is currently the most accurate measure available for anxiety level because an emotion seems only possible to be measured effectively by asking individuals how they feel. The physiological and behavioural measures of anxiety discussed elsewhere in this thesis cannot be regarded as independent measurements of anxiety. That is partly related to the concept of arousal. For example, high levels of physiological and behavioural activity are associated with many states of emotion, not just anxiety. When one considers how quickly enjoyable excitement can change to anxiety with virtually no provocation, self-rating scales would require a very sensitive measure to detect the changes and still be a suitable indicator of the emotional state of anxiety.

## 7.5 The Benefits of This Research and Its Impact

The substantial benefit of this research is to further understanding of how people's social interaction changes in various settings of virtual worlds. This research was the initial study to examine the correlation between anxiety and factors causing the sense of presence in a computer-generated simulation of a job interview situation. The findings are valuable in identifying the key elements for presence settings in virtual environments in order to provoke significant anxiety, as it would be felt in a real situation. By understanding the elements in a virtual environment which provoke fear, for example a virtual human's appearance, gender, attitudes, graphic details, and the manner of communication, the research informs an appropriate platform allowing for the explanation of some psychological factors of reality in cyber therapy. This could enhance future developments in the effectiveness of virtual reality therapy and optimise treatment approaches.

This research confirmed that the anxiety stimuli could be adjusted by VR components such as graphical details, attitudes of avatar, or visual displays. The findings suggest the concept of a flexible therapeutic virtual environment to manage anxiety stimulus parameters in a gradual manner. The multiple stimulus parameters could be controlled in real-time, and explicit stimuli which influence the dysfunctional response can be isolated. For example, the intensity of exposure can be adjusted by different graphic details or the communication manner of avatars according to the specific needs of the participant. We believe that these are notable innovations in the therapeutic process. It will help enhance the effectiveness of VRET for the fear of social interaction.

We have developed a job-interview scenario taking place in a virtual office environment. Previous VRETs have not reproduced the job-interview as a context of anxiety stimulus, despite the fact that the job-interview is one of the commonest situations in symptoms of social phobia. This research has verified that the job-interview scenario is an appropriate social interaction in a virtual environment to activate anxiety among various social situations in real life. Future work using the virtual job-interview scenario could have a therapeutic use in social phobia care.

From a technological point of view, the feature of virtual simulation that was developed for this project is superior, in terms of technical improvements, to all previous studies. Avatars in this real-time simulation were developed using the most recent modelling and rendering software and hardware. The system allowed the investigator to select a virtual character at any time among pre-created avatars and control the avatar's animation with simply the click of a mouse or short-cut keys. This simplified user-interface might provide some benefits to end-users who are probably non-technical individuals, such as clinical therapists or psychological consultants. The high fidelity of virtual environment will help enhance the acceptance of VR technology within the clinical community. Moreover, the system supports both HMD- and LCD-based immersive environments running together with real-time psycho-physiological monitoring devices. Such integrated and advanced virtual environments might enhance a therapeutic or diagnostic intervention that is appropriate in the case of an anxiety-activating system. The only limitation of this system relates to the real-time rendering processes for more realistic appearance and animations. However, future improvements in computer technology should significantly improve the graphics and animations in applications that can be used for real-time virtual reality exposure therapy.

## 7.6 Summary

This chapter summarised the main findings of this research, and discussed its potential impact, limitation and issues about its general applicability. The overall findings of this research were:

- ✓ Some degree of anxiety can be provoked by controlling virtual stimulus thresholds.
- ✓ Appropriate realism of VR stimuli is essential in sustaining the state of anxiety over the course of VR exposure.
- ✓ The factor of avatarsh appearance and behaviour significantly influenced the activation of fear in individuals during the VR exposure.
- ✓ The immersive level of VR apparatus was also correlated to the degree of activation of anxiety.
- ✓ The high fidelity of virtual environment generally provoked a greater degree of anxiety, but the aspects of VR fidelity could be changed by the mental representation of individuals to the context of the stressful situation.

This chapter also discussed the issues surrounding the potential effects of behavioural fidelity of virtual avatars, the effects of changing conditions on experimental settings for measuring anxiety, validity of physiological responses, and accuracy in self-rating scales. The benefits of this research were the identification of critical components for activating anxiety in virtual environments, and the suggestion of a framework for an integrated and advanced virtual environment for the purpose of therapeutic and diagnostic intervention for social anxiety disorder.

CHAPTER 8

# Conclusions and Future Work

Virtual Reality has been introduced into the field of psychotherapy over the past decade. A number of researchers and psychologists have attempted to demonstrate the feasibility of VR as a psychotherapeutic intervention for mental health care. To date, various studies have been undertaken to verify the efficacy of VR over conventional in-vivo or imaginal exposure therapy, in particular for several specific phobias such as acrophobia, social phobia, aerophobia, and arachnophobia. While these past studies have successfully shown the benefits of VR to the treatment of phobias, a number of innovations and improvements in the simulation of virtual reality may still be required before this approach is likely to be widely adopted.

Social phobia is one of the most common types of phobia in any society. The feature of social phobia is that this psychological struggle is not limited to a certain situation, and is often accompanied by major depression or substance abuse. It thus requires more sophisticated and assorted clinical techniques. With the awareness that fear can be aggravated in social situations, several researchers have proposed a framework of VRET for social phobia. Although a number of challenges have been overcome, this area is still in its infancy. In order to add significantly to our understanding of VR and phobias, this thesis developed an anxiety-activating virtual simulation with state-of-the-art VR technology, and investigated the relationship between perceptual presence factors and human anxiety in a fear-stimulating virtual social situation.

## 8.1 Contributions to Knowledge

This research offered the following contributions to the knowledge of VRET. The substantive contributions include experimental findings regarding the effect of particular aspects of VR fidelity on a variety of anxiety responses. The methodological contributions suggest research approaches to studying these relatively novel phenomena.

### 8.1.1 Informing an Advanced VRET for Job-Interview Fear

This research has introduced an advanced VRET developed not only for delivering an anxiety-provoking virtual job-interview simulation with a high-quality immersive system that was similar to any professional VR simulation, but also for providing measurement devices such as an eye-tracker and bio-amplifier to monitor information in real-time about a patient's physical and physiological anxiety state over the course of the exposure. Although the general applicability of the VR system in clinical use was not in the subject of this research, the experimental studies conducted clearly demonstrated the possibility of provoking anxiety sufficient to form part of a therapy for social phobia. Furthermore, the solution we have proposed is low-cost, ie. using off-the-shelf technology, and thus affordable to those wishing to help people overcome social phobias, including job-interview anxiety. The creation of the intervention was a new contribution, as was the integration of the anxiety measures to capture real-time data. The findings from the experimental studies using the intervention were also a new contribution to knowledge.

### 8.1.2 Expending knowledge on the impact of VRET components

This research mainly expanded our knowledge of virtual reality therapy for job interview fear. A series of experimental studies in this research demonstrated the effect of realism of VR components and their relationship to anxiety levels in the simulation of social-interaction. This evaluation thus contributed significantly to a deeper understanding of the role of virtual avatars and apparatus in the study of VRET, as well as offering virtual reality developers a framework for the construction of an effective VR intervention for social phobia care. The analysis of the relationship between elements of the virtual environment and the level of anxiety provoked was a new contribution to knowledge.

### 8.1.3 Conducting a Systematic Review and Meta-Analysis

This research proposed the evidence for the effectiveness of virtual reality exposure therapy in social phobia through a systematic review and meta-analysis. Although these methods are not common in engineering studies, these approaches were very useful to the scientific evaluation for the critical components and its potential outcomes in VRET. The information gathered in this stage was used to develop an actual intervention and study design. The feasibility of this intervention was then tested by a number of experimental studies. The synthesis of the literature in this area was a new contribution to knowledge.

### 8.1.4 Proposing Methodological Contributions in the Manner of Collecting Anxiety Responses

This research also added methodological contributions in the manner in which anxiety responses may be collected over the course of the VR exposure. The approach of combining behavioural, physiological and verbal measurements allowed us to attain a full understanding of individuals' behaviour tendencies and their subjective responses to the anxiety-stimulating virtual environment. This framework may be beneficial for others wishing to obtain complex anxiety responses, and thus in determining the state of anxiety of participants. In particular, the eye-tracker offers very detailed visual results and both a qualitative and quantitative appraisal of an individual's eye-contact avoidance behaviours. Using this device it was possible to not only observe the tendency of gaze fixation, but also measure eye scan-path, eyelid aperture, eyebrow movement and eye-blink. In addition, the use of a bio-amplifier to collect physiological responses such as pulse rate and skin conductance responses provides greater benefits to the collection of computerised data, which enables consistent measurements of the stimulation of emotional states. However, the ability to accurately interpret an individual's anxiety state from the results of physiological responses is limited, and the responses showed restricted validity due to individual differences. The actual usage of these measures for determining the level of anxiety is not innovative, but this study clearly showed the benefits that can be gained by integrating them into a VRET system. Such an integration can allow a patient's anxiety state to be monitored in real-time as well as contribute to an understanding of the genesis of psychological struggle while exposed to VRET.

## 8.2 Recommendations for Future Research

This research has been carried out to investigate the human anxiety state during the course of a job-interview simulation. The state of anxiety was identified using a combination of behavioural, verbal, and physiological approaches. As discussed in Chapter 3, the issues surrounding the measurement of anxiety are complex and technical due to anxiety being associated with multiple channels, such as subjective experience, facial action, central and peripheral nervous-system activation, cognitive processing changes, and behavioural tendencies. To analyse and determine these characteristics of anxiety, long lists of measurements have been developed, but these are still not perfect in terms of recording the state of anxiety objectively. We believe our selection of measurements is significant in determining the state of anxiety, but this should be investigated further using other types of measurements. Furthermore, the observations in this research were undertaken within an artificially controlled and constricted environment. While the investigations were experimentally validated, it is difficult to predict how these findings would generalise to other conditions. However, the findings of this research can be used generate hypotheses for studies of further aspects of the activation of anxiety in VR environments. In order to generalise the findings, more investigation is required with large numbers of (*diverse*) subjects.

From the experience of this research, we can make several suggestions about the selection of measurements. A rating scale might be the most appropriate form of measurement to use if the aim of the study is to investigate a specific type of pathological anxiety. A questionnaire, or similar method, could be effective when investigating the level of anxiety at a particular point in time. Rating scales enable valid and reliable data to be obtained, but this data focuses more on the subject's background and history of symptoms of anxiety and can regard fear and avoidance as of equal importance. Thus, in order to measure the state of anxiety at a certain point, a questionnaire seems the most appropriate method of measurement. In addition, the selection of participants is always a contentious issue in this type of research. Fortunately, the participants in our research did not show obvious differences in terms of the severity of their anxiety symptoms. However, it seems that anxiety responses are often affected by individual differences such as age, gender, ethnicity, personality, and so on. Thus, the use of screening instruments or a minimum knowledge of a participant's history may be helpful in order to estimate the expected reaction before determining the levels of anxiety.

Of the various perceptual factors in VRET, this research was only concerned with the factor of realism. Thus, more research is required to investigate the relationship between the levels of the participant's anxiety and other factors from the avatar and the environment itself, including the avatar's voice tone or manner of speech, gender, and ethnicity, and the environment's smell, lighting, and so on. Moreover, future research needs to identify how various perceptual factors in VR affect the treatment outcomes in VRET for social phobia. This type of investigation might contribute to the implementation of this type of VR system into clinical settings. Further comparison studies are also required to address the issue of implementation. For example, the VRET needs to be compared to conventional clinical therapies with appropriate sample sizes and methodologies. In addition, VR has not yet been shown to be superior to other forms of computer-assisted psychotherapy (*e.g web-based therapy*).

## 8.3 Final Word

Realistic virtual environments have the potential to play a leading role in helping people overcome their social phobias. This thesis is one more step on the path to a full understanding of just how such virtual environments should be designed and implemented in order to provide efficient and appropriate help for these debilitating social conditions.

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APPENDIX A

# Self-Rating Scales for Anxiety Measure

A.1 : Brief Fear of Negative Evaluation Scale

A.2 : Liebowitz Social Anxiety Scale

A.3 : The Measure of Anxiety in Selection Interviews

## A.1 BFNE scale

**Project Title: Virtual Reality Job Interview**

**Initial Name:**
**Email:**

**These questionnaires will help us to identify your level of social anxiety, performance anxiety, or public speaking anxiety. Please read the instruction bellow carefully before you start.**

Check all the situations with range from 0 to 5 according to your sense of fear or avoidance.

- 0 is the situation when you feel fear or you would like to avoid the least likely.
- 5 is the situation when you feel fear or you would like to avoid the most likely.

**Thank you for your cooperation.**

| | **Brief Fear of Negative Evaluation Scale** | Least Most |
|---|---|---|
| 1 | I worry about what other people will think of me even when I know it doesn't make a difference. | 0 1 2 3 4 5 |
| 2 | I am unconcerned even if I know people are forming an unfavorable impression of me. | 0 1 2 3 4 5 |
| 3 | I am frequently afraid of other people noticing my shortcomings. | 0 1 2 3 4 5 |
| 4 | I rarely worry about what kind of impression I am making on someone. | 0 1 2 3 4 5 |
| 5 | I am afraid that others will not approve of me. | 0 1 2 3 4 5 |
| 6 | I am afraid that people will find fault with me. | 0 1 2 3 4 5 |
| 7 | When I am talking to someone, I worry about what they may be thinking about me. | 0 1 2 3 4 5 |
| 8 | I am usually worried about what kind of impression I make. | 0 1 2 3 4 5 |
| 9 | If I know someone is judging me, it has little effect on me. | 0 1 2 3 4 5 |
| 10 | If I know someone is judging me, it has little effect on me. | 0 1 2 3 4 5 |
| 11 | Sometimes I think I am too concerned with what other people think of me. | 0 1 2 3 4 5 |
| 12 | I often worry that I will say or do the wrong things. | 0 1 2 3 4 5 |

## A.2 LSAS scale

Check all the situations with range from 0 to 3 according to your sense of fear and avoidance.

- 0 is the situation when you feel fear and you would like to avoid the least likely.
- 3 is the situation when you feel fear and you would like to avoid the most likely.

| **Liebowitz Social Anxiety Scale** | | Least (0) —- Most (3) | | | | |
|---|---|---|---|---|---|---|
| 1 | Telephoning in public | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 2 | Participating in small group | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 3 | Eating in public places | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 4 | Drinking with others in public places | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 5 | Talking to people in authority | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 6 | Acting, performing, or giving a talk in front of an audience | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 7 | Going to a party | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 8 | Working while being observed | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 9 | Writing while being observed | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 10 | Telephoning someone you don't know very well | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 11 | Talking with someone you don't know very well | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 12 | Meeting strangers | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 13 | Using public bathroom/toilet | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 14 | Entering a room when others are already seated | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 15 | Being the center of attention | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 16 | Speaking up at a meeting | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 17 | Taking a written test | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 18 | Expressing appropriate disagreement or disapproval to people you don't know very well | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 19 | Looking at people you don't know very well in the eyes | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 20 | Giving a report to a group | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 21 | Asking someone out on a date | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 22 | Returning goods to a store where returns are normally accepted | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 23 | Inviting people to a dinner party | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |
| 24 | Resisting a high pressure sales person | Fear | 0 | 1 | 2 | 3 |
| | | Avoidance | 0 | 1 | 2 | 3 |

## A.3 MASI scale

**Measure of Anxiety in Selection Interview**

Items are rated on a 5-point response scale:
**1 = Strongly disagree** , **2 = Disagree**, **3 = Feel natural**m **4 = Agree**m **5 = Strongly Agree**

| **Items** | | Response Scale | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| 1 | I become so apprehensive in job interviews that I was unable to express my thoughts clearly | | | | | |
| 2 | I got so anxious while taking jobs interviews that I had trouble answering questions that I know | | | | | |
| 3 | During job interviews, I often could not think of a thing to say | | | | | |
| 4 | I felt that my verbal communication skills were weak | | | | | |
| 5 | During job interviews I found it hard to understand what the interviewer was asking me | | | | | |
| 6 | I found it difficult to communicate my personal accomplishments during a job interview | | | | | |
| 7 | In job interviews, I got very nervous about whether my performance was good enough | | | | | |
| 8 | I was overwhelmed by thoughts of doing poorly when I was in job-interview situations | | | | | |
| 9 | . I worried that my job-interview performance would be lower than that of other applicants | | | | | |
| 10 | During a job interview, I was so troubled by thoughts of failing that my performance was affected | | | | | |
| 11 | During a job interview, I worried about what would happen if I didn't get the job | | | | | |
| 12 | While taking a job interview, I worried about whether I was a good candidate for the job | | | | | |
| 13 | During a job interview, my hands shook | | | | | |
| 14 | It was hard for me to avoid fidgeting during a job interview | | | | | |
| 15 | My heartbeat was faster that usual during job interviews | | | | | |
| 16 | Job interviews often made me perspire (e.g., sweaty palms and underarms) | | | | | |
| 17 | My mouth got very dry during job interviews | | | | | |
| 18 | I often felt sick to my stomach when I was interviewed for a job | | | | | |

APPENDIX B

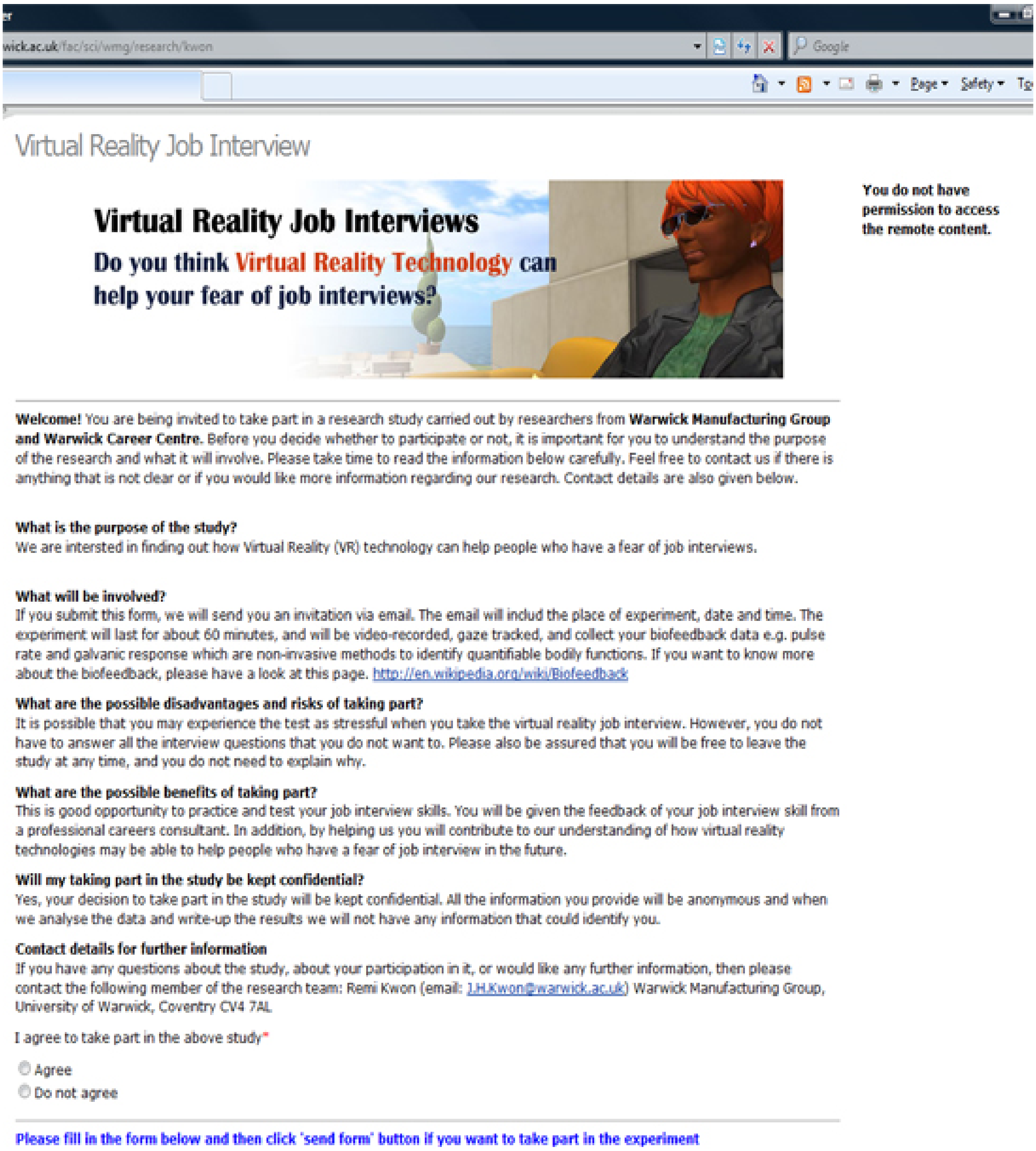
# Materials for Experiment Study

B.1 : Study Website http://www2.warwick.ac.uk/fac/sci/wmg/research/kwon

B.2 : Advertisements

B.3 : Consent Form

## B.1 Study Website



wick.ac.uk/fac/sci/wmg/research/kwon

Virtual Reality Job Interview



You do not have permission to access the remote content.

**Welcome!** You are being invited to take part in a research study carried out by researchers from **Warwick Manufacturing Group and Warwick Career Centre**. Before you decide whether to participate or not, it is important for you to understand the purpose of the research and what it will involve. Please take time to read the information below carefully. Feel free to contact us if there is anything that is not clear or if you would like more information regarding our research. Contact details are also given below.

**What is the purpose of the study?**
We are intersted in finding out how Virtual Reality (VR) technology can help people who have a fear of job interviews.

**What will be involved?**
If you submit this form, we will send you an invitation via email. The email will includ the place of experiment, date and time. The experiment will last for about 60 minutes, and will be video-recorded, gaze tracked, and collect your biofeedback data e.g. pulse rate and galvanic response which are non-invasive methods to identify quantifiable bodily functions. If you want to know more about the biofeedback, please have a look at this page. http://en.wikipedia.org/wiki/Biofeedback

**What are the possible disadvantages and risks of taking part?**
It is possible that you may experience the test as stressful when you take the virtual reality job interview. However, you do not have to answer all the interview questions that you do not want to. Please also be assured that you will be free to leave the study at any time, and you do not need to explain why.

**What are the possible benefits of taking part?**
This is good opportunity to practice and test your job interview skills. You will be given the feedback of your job interview skill from a professional careers consultant. In addition, by helping us you will contribute to our understanding of how virtual reality technologies may be able to help people who have a fear of job interview in the future.

**Will my taking part in the study be kept confidential?**
Yes, your decision to take part in the study will be kept confidential. All the information you provide will be anonymous and when we analyse the data and write-up the results we will not have any information that could identify you.

**Contact details for further information**
If you have any questions about the study, about your participation in it, or would like any further information, then please contact the following member of the research team: Remi Kwon (email: J.H.Kwon@warwick.ac.uk) Warwick Manufacturing Group, University of Warwick, Coventry CV4 7AL

I agree to take part in the above study*

- Agree
- Do not agree

**Please fill in the form below and then click 'send form' button if you want to take part in the experiment**

## B.2 Advertisements

Poster

**Are you afraid of job interview?**

Warwick Career Service and Warwick Manufacturing Group provide job interview practices both in Virtual Reality and Real.

We provide

- £ 5 book voucher
- Job interview practices both in Virtual Reality and Real World
- Feedback (we will record and analyse your behaviour with professional equipments)

Please contact **Remi Kwon** if you are interested.

**J.H.Kwon@warwick.ac.uk**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk | **Job interview practice** Jh.kwon@warwick.ac.uk |

Web-banner

## B.3 Consent Form

# Informed Consent Form

Warwick Medical School & Warwick Digital Laboratory, University of Warwick

THE UNIVERSITY OF WARWICK

# Project Title: Virtual Reality Job Interview

Please fill in the blanks or boxes (x)

**Full Name:**

* Please place a cross in the box

| | | |
|---|---|---|
| 1. | I confirm that I have read and understand the information sheet (version 3.0) for the above study. I have had the opportunity to consider the information and ask questions. | X |
| 2. | I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. | X |
| 3. | I understand that quotations from the interview may be used in writing up the results of the research and that these will always be anonymous and not attributed to me in any way. | X |
| 4. | I understand that my basic personal information will be securely stored for the duration of this study | X |
| 5. | I understand that the interview will last for about 60 minutes, and will be audio, video-recorded. | X |
| 6. | I agree to take part in the above study. | X |

Please sign both copies. Keep one and give the other back to the investigator Jounghuem Kwon, once the interview takes place. If you have any other questions to direct to the research team, contact Jounghuem Kwon by email (j.h.kwon@warwick.ac.uk).

**Date** **Signature**

**Researcher**