Experimental Studies of the Interaction between People and Virtual Humans with a Focus on Social Anxiety

Xueni Pan

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Department of Computer Science
University College London

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To my parents

I, Xueni Pan, Confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Psychotherapy has been one of the major applications of Virtual Reality technology; examples include fear of flying, heights, spiders, and post-traumatic stress disorder. Virtual reality has been shown to be useful, in the context of exposure therapy for the treatment of social anxiety, such as fear of public speaking, where the clients learn how to conquer their anxiety through interactions with Virtual Characters (avatars).

This thesis is concerned with the interaction between human participants and avatars in a Virtual Environment (VE), with the main focus being on Social Anxiety. It is our hypothesis that interactions between people and avatars can evoke in people behaviours that correspond to their degree of social anxiety or confidence. Moreover the responses of people to avatars will also depend on their degree of exhibited social anxiety – they will react differently to a shy avatar compared to a confident avatar.

The research started with an experimental study on the reaction of shy and confident male volunteers to an approach by an attractive and friendly virtual woman in a VE. The results show that the participants responded according to expectations towards the avatar at an emotional, physiological, and behavioural level. The research then studied a particular cue which represents shyness – "blushing". Experiments were carried out on how participant responds towards a blushing avatar. The results suggested that, even without consciously noticing the avatar's blushing, the participants had an improved relationship with her when she was blushing. Finally, the research further investigated how people respond towards a shy avatar as opposed to a confident one. The results show that participants gave more positive comments to the personality of the avatar displaying signs of shyness.

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> *"The elegant man has got out of the limousine and is smoking an English cigarette. He looks at the girl in the man's fedora and the gold shoes. He slowly comes over to her. He's obviously nervous. He doesn't smile to begin with. To begin with he offers her a cigarette. His hand's trembling…..She says she doesn't smoke, no thanks. She doesn't say anything else, doesn't say leave me alone. So he's less afraid. He tells her he must be dreaming. She doesn't answer. There's no point in answering, what would she say? She waits……"*
>
> — *Marguerite Duras, "L'Amant", 1984*
> *(Translated by Barbara Bray, "The Lover", 1986)*

Chapter 1 Introduction

In the quote above from her very famous novel, Duras has accurately portrayed the anxiety flow behind this elegant gentleman's first approach to a girl he's interested in. His nervousness was obvious: he felt awkward; he moved slowly, he didn't know what to say; he was afraid of being rejected, so afraid that his hand was trembling, which just made him feel more awkward…

In reality, this embarrassing moment has been experienced by many people, maybe at different levels, while approaching or being approached by someone of the opposite sex. Most people may have experienced similar anxiety while speaking in front of authority figures, strangers, or while interacting with people in general. Shy people, especially people with social phobia sometimes experience extreme discomfort and anxiety, and will seek to avoid social interactions whenever possible (American Psychiatric Association. Task Force on 1994). However, will they have the similar anxiety when interacting with a Virtual Character in Virtual Reality (VR)? Will it make it easier if the Virtual Character behaves very positively? Or behaves shyly, as the user himself? Will it help shy people to build confidence by talking with a 'shy' Virtual Character? In the following, we first consider what is Virtual Reality and the effect that an experience can have on people.

1.1 Virtual Reality and Presence

VR uses computer representations to transform people's sense of presence, so that they feel themselves to be somewhere else rather than where they are. An

immersive Virtual Environment aims to create a strong sense of being in the virtual world with computer simulated surroundings, which is achieved through visual and auditory displays, and sometimes haptic feedback. Typical Virtual Environment interfaces include head mounted displays (HMDs) and CAVE-like system.

A common framework for measuring the responses of people to Virtual Environment (VE) is “presence" which could be defined as “the psychological sensation” of being somewhere rather than just seeing images presented in the VE (Casanueva and Blake 2001).

Sanchez-Vives and Slater argued that presence may be defined as the extent to which participants act and respond as if what they experience in the Virtual Reality were real (Sanchez-Vives and Slater 2005). For instance, when standing on top of a virtual cliff, one would experience similar anxiety as in real life. They would react towards it unconsciously (increased heart rate) and consciously (aware of the fear). This tendency of acting realistically towards virtually generated data distinguishes VE from all other media, such as films and books, and therefore leads to a range of beneficial applications from virtual psychotherapy to training.

1.2 Research Question

Virtual Characters (avatars) are computer generated human beings. They are employed in VR with the intension of creating a more natural and friendly interaction with the users, by invoking their automatic response at a physiological as well as an emotional level. Therefore, similar to an everyday life interaction, avatars are normally designed to interact with users through language, body movements, and facial expressions, in order to achieve an automatic emotional response.

When a Virtual Character smiles at you, will you smile back, and why? Previous research has shown that people respond towards avatars realistically (Slater, Steed et al. 1998; Slater, Sadagic et al. 2000; Slater and Steed 2002), so that the appearance and actions of the avatars influence the way people react towards them. This thesis is to explore different ramifications of the situation when people interact with avatars in different scenarios. We examine, using experimental studies, how the avatar’s behaviour influences the state of the participants, at an emotional, behavioural, and physiological level. In particular, we are interested in discovering

the potential for using the impact that avatar might have on human participants in psychotherapy for social phobics.

However, building *believable* avatars with *natural* behaviour is not easy. In the real world, the behaviour of a human being is affected by many aspects that can be long term (personality, circumstance, relationship) and short term (mood, health condition) (Poggi, Pelachaud et al. 2005); the outcome in terms of degree of believability is therefore a complicated combination of these various aspects. On the other hand, human beings are very sensitive to human-like behaviours and they can easily tell if the avatar behaves inappropriately. As a result, the behaviour of the Virtual Characters can look "wooden", with a lack of emotional range or a lack of adaptation to the users' attitude towards the character, and with very little 'depth' in their responses (Vinayagamoorthy, Gillies et al. 2006).

Research in avatar behaviours has focused on creating complex emotion models behind human behaviour rather than studying how artificially generated behaviour affects a real human's emotional responses. For instance, a lot of research has assumed that modelling sophisticated facial expressions will automatically improve the potential communication between human participants and avatars. However, is this a good assumption?

In this work we have reviewed the psychology literature regarding shyness related behaviour, and attempted to animate avatars using that knowledge. Most importantly, in order to validate those animations, we carried out experimental studies with human participants throughout the whole project.

1.3 Scope of the thesis

Firstly, the research presented here looks at shy behaviour and associated emotions. Moreover, avatars 'express' themselves through many different channels, such as: language, gesture, posture and facial expressions. Here we focus on non-verbal communication, most importantly facial expression and bodily movements.

Secondly, to represent shy behaviour we are looking at something good enough to work with human participants rather than with the best possible graphics. Methods for rendering visually highly realistic characters are not part of the scope of this thesis.

Moreover, we have chosen blushing as a topic for study in depth, because as a response related to shyness blushing serves an important function in human communication; yet, as an additional facial feature, it has not been mentioned much in the computer animation literature. As part of this research we have studied the representation of blushing. However, again, blushing was implemented as something noticeable yet without striving for photorealism.

Finally, we are particularly interested in how participants respond to our avatars. For that reason, experimental studies were carried out throughout the whole research with human participants, with special attention to the relationship between male participants and female avatars.

1.4 Thesis objective and contributions

The main contribution of this research is:

- This thesis explored interactions between human participants and Virtual Characters with three experimental studies carried out in VEs which focused on social anxiety. In this research, we have studied the under-researched area of how human participants respond to Virtual Characters in an interpersonal communication. In particular, we have focused on the role that social anxiety plays in a face-to-face interaction between a participant and a life-size avatar in a VE. To evaluate the level of social anxiety generated in such interactions and how it could influence the interaction, we observed not only participants' questionnaire and physiological responses but also their behavioural responses, particularly, their bodily movements during the interaction. Our results have supported that participants react towards the avatar realistically at a subjective, physiological, and behavioural level. The findings of this thesis have contributed to the understanding of how social anxiety interferes with human-avatar interaction in a VE, as well as giving insights into certain behaviours related to social anxiety in real life psychology.

Other contributions include:

- A literature review of the facial expression literature and facial animation systems.

- A literature review of social blushing and its implementation in facial animation.
- A literature review on using participants' body movements in evaluations of Virtual Reality.
- A methodology for implementation of a facial animation system driven by complex mental states.
- Creation of characters that behave shyly.

1.5 Structure of the Thesis

Given the research interest and the list of the objectives stated in this Section, in the following Chapter we report the literature review on facial expressions (2.2), background study on shyness and social phobia (2.3), social blushing (2.4), methods of evaluation (2.5), and the use of VR in psychotherapy (2.6).

Chapter 3 presents two technical approaches in animating the face with machine learning algorithms and the body with motion captured data.

Chapter 4 describes the experimental study in a bar scenario, where we invited male participants to interact with a forward virtual woman.

Chapter 5 gives the details of the experimental study on blushing.

Chapter 6 presents the experimental study on how male participants react towards a shy virtual woman in a virtual interview.

Chapter 7 concludes the whole research.

Chapter 2 Literature Review

2.1 Overview

This research concerns the interaction between people and avatars in Virtual Environments, with the focus on Social Phobia. Therefore our interests lay in the design and implementation of realistic human-avatar interactions and the evaluation of such interactions, in particular, the possibility of using such interactions in psychotherapy for social phobics.

As a first step to achieve immersive interaction in VE, we look in to the implementation of realistic avatars with emphasis on facial expressions (Section 2.2).

We then review the psychological background of social phobia in Section 2.3, which is also part of our main focus of this thesis. In particular, we examine the behaviours related to social anxiety. This will further broaden our knowledge in social phobia and methods of representing social anxiety or shyness in VR.

In Section 2.4, we further look into a particular facial feature: blushing. The reason for this is that it is a very important focus in psychological studies related to Social Phobia but yet has been neglected in facial animations. Our focus here is to design and implement an experimental study in VR to exam how people respond towards a blushing avatar (see Chapter 5).

Another important aspect of this thesis is the evaluation of human-avatar interaction. In Section 2.5 we review the methods of evaluation.

Our final goal is to use this human-avatar interaction in Psychotherapy for social phobics. In Section 2.6 we review the existing applications of using VR in psychotherapy.

2.2 Facial Expressions

One of the most expressive areas of the body is the face which is the area most closely observed during an interpersonal communication (Argyle 1969). Facial expressions have been well studied and categorized by researchers in accordance to main expressions (Ekman, Friesen et al. 1978; EKman 1982; Wehrle, Kaiser et al. 2000), responses (Osgood 1966), and basic physical movements (Birdwhistell 1968). Most methodological research has focused on how emotions are expressed as facial expressions. However, the display of emotions through the face is only one side of

the coin. Facial expressions are also used to support the speech, adding new or redundant information (Bavelas and Chovil 1997; Poggi and Pelachaud 2000; Pelachaud and Bilvi 2003). The following Sections deal with the types of facial expressions and their significance.

In the following we first introduce from the technique view the current approaches to facial animation, and then in depth the psychological background behind. Finally we review its function in social interactions.

2.2.1 Approaches to Facial Animation

In real faces the basic motion primitives are the movements of the muscles of the face. In graphical characters, motion is controlled by deforming the underlying meshing, either directly (Parke 1972), or by using more sophisticated techniques such as techniques such as Bézier or B-spline patches and abstract muscles (Parke and Waters 1994; Bui 2004). To obtain the natural movement of human facial expressions using linear interpolation of facial mesh data is not sufficient so other methods are often used. For example, Parke (Parke 1972) used a cosine interpolation scheme to approximate the acceleration and deceleration of facial movements.

One of the major contributions to the analysis of facial expressions is the Facial Action Coding System (FACS) developed by (Ekman, Friesen et al. 1978). In this system, Action Units (AU) are defined as the contraction/relaxation of facial muscles and are used to describe almost all anatomically possible facial expressions. An example of AU could be “Inner Brow Raiser” or “Lip Corner Depressor”. A less detailed implementation (Thórisson 1996) provides a simpler way that allows animation with a more cartoon style look. In this approach, control points such as “Brow Right Medial” and “Mouth Left” were selected to maximise the expressively/complexity trade-off.

The FACS is very useful in representing facial appearances, however, it does not cover everything we need to analysis/describe facial expressions. First it does not contain some additional facial features such as facial wrinkles and tongue movement. Secondly, it provides no information about the meanings conveyed through facial expressions. Different from the local approach as FACS has taken,

there are other global (full face) approaches such as Affective Presentation Markup language (AMPL) (Pelachaud and Bilvi 2003), and Facial Animation Parameters (FAPs) defined by MPEG-4 standard (Hartung, Eisert et al. 1998; Pirker and Krenn 2002).

2.2.2 Facial Expressions and Expression of Emotion

Table 2.1: Different Definitions of Basic Emotions (Ortony and Turner 1990)

Theorist	**Basic Emotions**
(Arnold 1960)	Anger, aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness
(Ekman, Friesen et al. 1982)	Anger, disgust, fear, joy, sadness, surprise
(Frijda 1986)	Desire, happiness, interest, surprise, wonder, sorrow
(Gray 1985)	Rage and terror, anxiety, joy
(Izard 1971)	Anger, contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise
(James 1884)	Fear, grief, love, rage
(McDougall 1926)	Anger, disgust, elation, fear, subjection, tender-emotion, wonder
(Mowrer 1960)	Pain, pleasure
(Oatley and Johnson-Laird 1987)	Anger, disgust, anxiety, happiness, sadness
(Panksepp 1982)	Expectancy, fear, rage, panic
(Plutchik 1980)	Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise
(Tomkins 1984)	Anger, interest, contempt, disgust, distress, fear, joy, shame, surprise
(Watson 1930)	Fear, love, rage
(Weiner 1984)	Happiness, sadness

A face is capable of producing about twenty thousand different facial expressions (Birdwhistell 1970). However, two strangers, even from completely

different backgrounds, are still able to distinguish certain emotions from the face of each other. A limited set of emotional facial expressions thus are selected and defined as *basic* emotions, which are universally recognised emotional facial expressions. Nevertheless, it is still an arguable issue between psychologists that which/how many emotions the basic emotions contain, as shown in Table 2.1.

The most popular one is by Ekman *et al.* (Ekman, Friesen et al. 1982). By their definition, the basic facial expressions are: Happy, Surprise, Fear, Angry, Disgust and Sad, as shown in Figure 2.1 (Ekman, Sorenson et al. 1969). This links well with the Blend Shape technique (Parke 1972) that animates faces using full face configuration.

Figure 2.1: The Six Basic Emotional facial expressions (reproduced from (Ekman, Sorenson et al. 1969)).

According to this theory, all emotions other than the basic ones are either subcategories or mixtures (Russell 1997). For instance, both fury and annoyance are subcategories of anger. Therefore fury and annoyance share anger's facial signal, but

with different intensities. Anxiety is a mixture of fear, sadness, anger, shame, and interest, so it is a blend of all those expressions.

As a special case, voluntary facial expressions can simulate spontaneous ones (Russell 1997), however, it does look different. For instance, a felt happy smile is usually marked by the action of both the zygomatic major muscle (muscle that pulls the lip corners upwards) and orbicularis oculi muscle (muscle around the eye) (Ekman and Friesen 1982). On the other hand, smiles that included traces of muscular actions associated with disgust, fear, contempt, or sadness usually occur when the subject is trying to mask negative emotions with a happy mask. A simulated smile is a combination of the smiling action (zygomatic major) with traces of the muscle movements from one or another negative emotion.

Emotions and emotional intensities are perceivable from an individual's face with a great deal of accuracy (Ekman, Friesen et al. 1978; Hess, Blairy et al. 1997). Darwin (Darwin 1993), Tomkins (Tomkins 1980), Ekman (EKman 1992), and Izard (Izard 1971) argue that emotions, particularly basic emotions, produce characteristic facial patterns. Ekman (EKman 1992), and Izard (Izard 1971) suggest that these sets of facial expressions are recognised across cultures as expressions of emotions. However, an experiment by Tomoko et al. (Koda 2004) shows that even in-between Chinese and Japanese cultures, some expressions can be interpreted with different meaning. For instance, the expression that Japanese people identify as "surprised" is interpreted as "confused" by Chinese people.

These facial displays occur during emotionally significant events. They are controlled by the individual but subconsciously and have particular physical and timing patterns related to the emotions they communicate. The resulting pattern is often considered a full-face configuration (Izard 1971; EKman 1992).

Carroll and Russell (Carroll and Russell 1996) argue that the context within which a facial expression is shown has a strong effect on the perceived emotion. If individuals are shown a static, emotionally expressive face with no clue to what elicited it, they imagine a context (Planalp and Knie 2002) and if the nonverbal behaviour is contradictory to the context, individuals will try to justify it (Argyle and Trower 1979). Therefore the context within which the emotional facial expression is displayed seems to play a significant role on how it is perceived.

Numerous facial animation systems display emotional expressions based on variants of a set of universally recognised facial expressions such as Ekman's (EKman 1982; EKman 1992). These systems either display one set of the universally recognised facial expressions (Velasquez 1997; Kshirsagar 2002; Bui 2004; Paiva, Dias et al. 2004) or in addition they produce combinations of these facial expressions (Heckelman and Schneier 1995; Kurlander, Skelly et al. 1996; Latta, Alvarado et al. 2002; Prashant and Meyer 2003; Raouzaiou, Karpouzis et al. 2003; Albrecht, Schröder et al. 2005).

For the selection of emotional expressions, certain systems use a static emotional representation (Kurlander, Skelly et al. 1996; Latta, Alvarado et al. 2002; Prashant and Meyer 2003; Raouzaiou, Karpouzis et al. 2003; Albrecht, Schröder et al. 2005) which do not take into account the evolution of emotion over time, such as the emotional wheel described by Plutchik (Plutchik 1980). The emotional wheel describes an emotional space through two dimensions: evaluation and activation (see Figure 2.2 (Whissell 1989)). Basic emotions corresponding to the universally recognised facial expressions are mapped onto this space. To display a new emotion, this emotion is mapped onto the wheel using the two dimensions and the combination of the universally recognised expressions corresponding to the two closest basic emotions is shown. Other systems use dynamic emotion representations which are responsible for the production of emotional expressions (Kshirsagar 2002; Bui 2004; Tanguy 2006). These types of systems represent the slow changes of emotional intensities and therefore provide a consistency mechanism to produce emotional expressions.

Mancini et al. developed a system in which a visual feedback is given to the user using a graphical representation of a human face (Mancini, Bresin et al. 2005). Using the real-time extraction and analysis of acoustic cues from the music performance, the system provides an interpretation of the emotional intention of the performer which is then represented as facial expression on an empathic agent. It uses a set of dimensions of expressivity (Hartmann, Mancini et al. 2006) to modify the animation of the agent qualitatively.

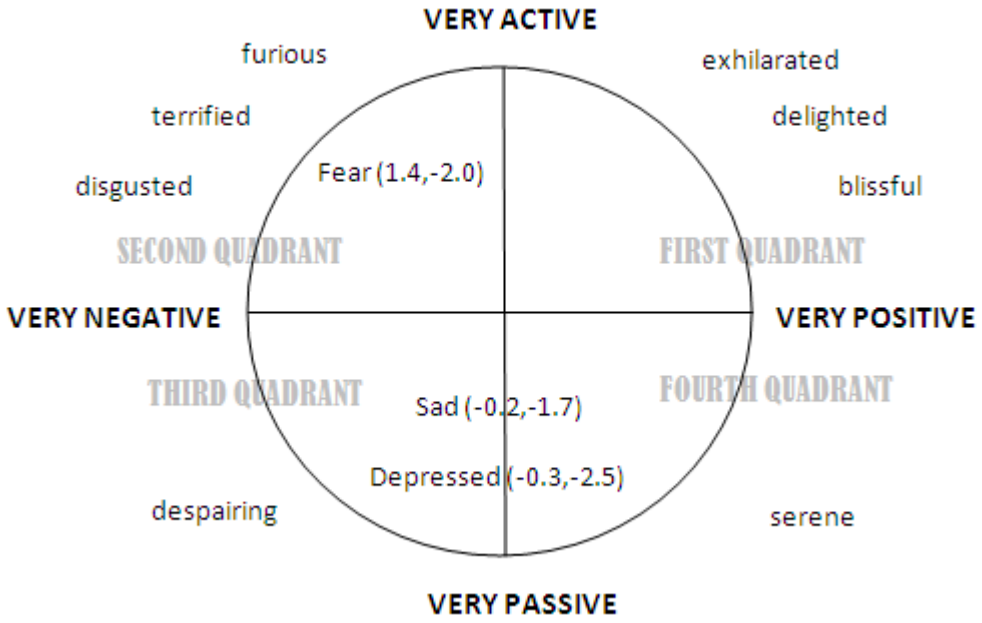


Figure 2.2: Whissel's activation-evaluation space model of emotions (Reproduced from (Whissell 1989))

2.2.3 Facial Expression and Social Interaction

Facial expressions emerge from the communicative process function as part of communicative acts. A communicative act is composed of two parts: a communicative meaning/function and a signal which is the physical realisation of the meaning (Bavelas and Chovil 2000). For instance facial signals such as eyebrows raised relate to emphasis.

Communicative acts are synchronised with speech adding new and/or redundant information. Communicative acts can be acted, symbolic or intentional, and arise due to the communicative process in contrast to emotional expressions which arise due to emotional events. Communicative acts are also fast due to their synchronisation with the speech, in comparison to emotional expressions which have their own time signatures. The meanings of communicative acts are varied. They could be syntactic, semantic (Bavelas and Chovil 1997) or related to the person's goals (Pelachaud and Bilvi 2003). Facial expression, as one of the communicative behaviours, depends on the communicative goal the person wants to pursue (Poggi, Pelachaud et al. 2005). The choice of the goal is determined by contingent events and long-lasting features. Contingent events include content to

communicate, felt emotions (physical resources), context and interlocutor. Long-lasting features refer to the agent's culture, personality and style, and so on.

Facial expressions are extremely important in interpersonal communication, providing many communicative functions such as emphasis (e.g. raising eyebrows), giving feedback as to whether a listener has understood (e.g. a confused expression) and distinguishing performatives (an order can be accompanied by a frown, a request by a smile) (Poggi and Pelachaud 2000). Experimental studies have shown that a combination of facial signals determines participant's perceived meaning including agree and accept (nod), like (smile), disagree and refused (head shake), dislike (frown and tension of the lips), disbelieve (frown and head tilt, or raise eyebrows), and don't understand (frown, or frown and head tilt) (Heylen, Bevacqua et al. 2007).

One important issue with the use of the face for social interaction is that several communicative functions could be expressed at the same time, which means that several facial signals should be displayed at the same time. If these facial signals involve the same facial part and try to communicate different meanings a semantic conflict occurs. The example given by Pelachaud and Bilvi (Pelachaud and Bilvi 2003) presents two communicative functions, a performative order and a comment which are realised as an "eyebrows frown" and an "eyebrows raised", respectively. As pointed out by the authors, "adding these two signals would not produce a believable expression", the communicated meaning would be sadness (Rosis, Pelachaud et al. 2003).

Another issue is the mapping between categories of communicative meaning onto facial signals. "The human face can generate around 50,000 distinct facial expressions, which correspond to about 30 semantic distinctions" (Paradiso 2002). As emphasised by Bavelas and Chovil (Bavelas and Chovil 2000), several signals could correspond to one communicative function and one signal could be used for several communicative functions. This shows the importance of taking context into consideration when interpreting the meanings of facial expressions. Physical implementations of facial meanings differ according to the physical and mental states of the speaker as well as the state of the dialogue (Bavelas and Chovil 2000) (Pelachaud and Bilvi 2003).

To solve the mapping problem, Tanguy uses a Dynamic Emotion Representation to represent emotional contexts in which physical implementations of facial meaning take place (Tanguy 2006). Thórisson also solves the mapping issue between signals and communicative meanings by taking into consideration the physical state of the character to select signals (Thórisson 1999). This solution also solves problems regarding semantic conflicts.

2.2.4 Summary

Facial expression serves an important role in interpersonal communication and has been a focus in character animation, with many different approaches to its implementation. However, very few studies look into the evaluation of facial animation with human participants. Moreover, some additional facial feature, for instance, blushing, has been neglected in its' implementation. We will further investigate the psychology and implementation of blushing in the Section after the next where we first review background on shyness and social phobia, which is a focus of our study.

2.3 Background on Shyness and Social Phobia

2.3.1 Definition of Shyness

Most human being have experienced different levels of "shyness" and "social anxiety", however, it means different things to different people (Schneier and Welkowitz 1996): many people are familiar with the anxious moment before giving a speech in front of a large group, or before going into a room full of strangers, other people experienced anxiety before making a phone call (Smith 1993); even some well adjusted people, who consider themselves not shy at all, sometimes may have hesitated long enough to miss out on chances to make a new friend or business contact, because of social anxiety (Schneier and Welkowitz 1996). Arbelle et al define shyness as a pattern of behaviour and emotional states which human beings have while, for example, approaching or being approached by other people in a social encounter (Arbelle, Benjamin et al. 2003).

As a common feeling shared by the majority of human beings, shyness, however, is not very much appreciated in most circumstances because of its unwanted symptoms. Shyness appears as either a blush on the face, trembling hand or

sweating. As a more extreme example, when interacting with a stranger for the first time, apart from all the somatic responds, some people may also have symptoms at a cognitive level such as fear of negative evaluation by others, and at a behavioural level (avoidance of social situations) (Heiser, Turner et al. 2003).

Embarrassment and shyness are very often referred to as the same thing in everyday life. The difference is shyness is to describe the characteristic of a person, while more often embarrassment to describe a situation (Crozier 1990). A shy person could be described as “easily embarrassed”; at the same time any confident person has experienced times when they are “embarrassed”. “Feeling shy” is a form of “being embarrassed”. In this thesis, we focus on the behaviour reflected in people’s everyday life and we do not distinguish these two concepts.

2.3.2 When Shyness Reaches an Extreme: Social Phobia

“A woman hates to stand in line in the grocery store because she's afraid that everyone is watching her. She knows that it's not really true, but she can't shake the feeling. While she is shopping, she is conscious of the fact that people might be staring at her from the big mirrors on the inside front of the ceiling. Now, she has to talk to the person who's checking out her groceries. She tries to smile, but her voice comes out weakly. She's sure she's making a fool of herself. Her self-consciousness and anxiety rise to the roof…” (Richards 2000)

The feeling described above is quite similar to shyness. In fact, the boundary between being shy and being Social Phobic is blurred (Heckelman and Schneier 1995). Heiser et al (Heiser, Turner et al. 2003) found that there is a significant and positive correlation between the severity of shyness and the presence of social phobia; however, social phobia is not merely severe shyness. Shyness normally does not interfere with our lives – it may stop us from going into a pub to chat with a stranger but not a supermarket to get food. Shyness is a vague feeling which more or less involves with many people’s life and it changes over time. On the other hand, Social Phobia is an Anxiety Disorder which impairs patients’ ability for daily life functioning.

Defined as a clinical disorder in the Diagnostic and Statistical Manual of Mental Disorders, Social Phobia is “A marked and persistent fear of one or more social

situations in which the person is exposed to unfamiliar people or to possible scrutiny by others" (American Psychiatric Association. Task Force on 1994).

Social phobia involves a strong fear of one or more social performance situations. Like the woman mentioned in the beginning of this Section, people with this condition fear that they will act in a way that is humiliating or embarrassing and that others will judge them negatively. Although recognize that this fear is irrational, they experience extreme discomfort and anxiety when in the feared situation and will seek to avoid the social encounter whenever possible (American Psychiatric Association. Task Force on 1994). For social phobics, the fear interferes significantly with their everyday life, including occupational (academic function), social activities and relationships.

In order to understand social phobia and represent shyness in character animations, in the following Section we look at behaviours related with shyness, or "social anxiety". This will help us understand how to represent shyness in character animation, with the goal of creating psychotherapy environment in VR for social phobics.

2.3.3 Behaviour related with Shyness

Before thinking about how to portray a shy avatar in Virtual Reality, let's first imagine someone being shy in real life: the immediate image could be a blushed face with an uncomfortable expression, the head slightly lowered, and in an awkward posture. In this Section we examine behaviours related with shyness, or "social anxiety".

In the psychologists' view, the expression of shyness and embarrassment is similar to the above image. Those expressions include: blushing, increased smiling, adverted gaze, more speech disturbances, more body motion, and stiff posture (Edelmann and Hampson 1981; Coll, Kagan et al. 1984; Asendorpf 1990). In 1966, Paul (Paul 1966) has developed a Timed Behavioural Checklist for Performance Anxiety, where 20 features associated with social anxiety was included, they are: paces, sways, shuffles feet, knees tremble, extraneous arm and hand movement, arms rigid, hands restrained, hand tremors, no eye contact, face muscles tense, face

"deadpan", face pale, face flushed (blushes), moistens lips, swallows, clears throat, breathes heavily, perspires, voice quivers, speech blocks or stammers.

Because our goal is to represent shyness in Virtual Characters, here we organise the shyness related into different categories: bodily movements, facial expressions, facial colour, voice and speech, and other, as presented in Table 2.2.

Table 2.2 Summary of Shy related behaviours

Categorise	**Behaviour**
Bodily movements	More body motion (sways, shuffles feet, knees tremble, extraneous arm and hand movement, hand tremors) Stiff posture (paces, arms rigid, hands restrained)
Facial expressions	Face muscles tense, face "deadpan", moistens lips
Facial colours	Blushing, face pale
Gaze	Adverted gaze (no eye contact)
Voice and speech	More speech disturbances (swallows, clears throat, breath heavily, voice quivers, speech blocks or stammers)
Other	Perspires

To blend these behaviours into our first image, we picture someone frequently moving their body yet with a stiff and awkward posture; their faces look deadpan, pale or red; they don't look at the other person in the eye, and they keep on moistening their lips; their speech is broken, they stammer, and their voice shaky. We can clearly identify whether someone is very anxious and embarrassed from the image. However, without seeing the whole picture, the result would be confusing: Edelmann and Hampson pointed out that embarrassed expressions on the face sometimes were identified as amusement, while together with body, embarrassment was more precisely indentified (Edelmann and Hampson 1981).

2.4 Social Blushing

After reviewing behaviours related to shyness, we have selected a particular facial feature to look at in more depth: blushing. As one of the "most peculiar and the most human of all expressions" (Darwin 1999), blushing has always been a popular topic in psychological studies. However, the psychology behind blushing is very difficult to understand because it is a facial feature that is not easy to generate voluntarily. In this Section we review this particular facial feature which is associated

social anxiety. We first review blushing from a psychological approach, and then we review implementations of blushing in character animation. This review also serves as the background study for our experimental studies as presented in Chapter 5.

2.4.1 Psychological studies on blushing

The purpose of this Section is to understand how people respond towards a blushing, and how to implement a blush in VR. We first review its physiological characteristics, and then discuss the possible reasons for blushing and how people respond towards it in real life.

2.4.1(a) What does blushing look like?

The first problem we need to address relates to the visual aspect of blushing. Blushing is usually accompanied by other actions that show embarrassment or shame. These behaviours include averted gaze, increased general body motion, the lack of fluent speech, and increased smiling (Edelmann and Hampson 1981; Asendorpf 1990).

The intensity of redness of human skin during blushing depends on the volume of blood rather than the rate of blood flow in the superficial vessels in the skin (Shields, Mallory et al. 1990). Frijda has suggested that the blush region is localized to the face, ears, neck and upper chest (Frijda 1986). In a review paper on social blushing, blushing has been defined “a spontaneous reddening or darkening of the face, ears, neck and upper chest that occurs in response of perceived social scrutiny or evaluation” (Leary, Britt et al. 1992). Leary and Meadows have found that blushing is often reported as accompanied with “face feels hot”, and “cheeks turn red or pink” (Leary and Meadows 1991). Similarly in an interview conducted by Shields, Mallory, and Simon, when asked about the blushing area, 68% of the participants described that blushing occurs primarily on the cheeks and only 26% said it occurs over the whole face (Shields, Mallory et al. 1990).

The literature suggests that blushing is associated with other behaviours related to embarrassment, and it appears as redness on people face. However, there is no clear agreement as to whether blushing occurs over the whole face, or primarily on the cheeks.

2.4.1(b) When does blushing occur?

In order to design the scenario of our experiments, we also needed to understand when people blush, although the reason why people blush is still a controversial issue amongst psychologists. In 1872 Darwin concluded that blushing is a physiological by-product of self-attention, "the thought that others think or know us guilty", but that it serves no other real function (Darwin 1999). Castelferanchi and Poggi's have suggested that blushing is the expression of shame in front of others (Castelfranchi and Poggi 1990).

Leary, Britt, Cutlip, and Templeton's review paper on social blushing have categorised the elicitors of blushing into four types: threats to public identity, praise and positive attention, scrutiny, and accusations of blushing (Leary, Britt et al. 1992). Threats to public identity refers to the fact that people often blush when they are concerned with how they are perceived and evaluated by others (Castelfranchi and Poggi 1990; Darwin 1999). One subjective experience that accompanies threats to one's public identity is embarrassment (Goffinan 1959). Praise and positive attention also trigger blushing because people may also worry that they will be unable to convey adequately their appreciation of others' recognition without appearing smug (Buss 1980; Schlenker and Leary 1985), or alternatively fear they will be unable to sustain an equally high performance in the future (Baumeister, Hamilton et al. 1985). Scrutiny refers to the situation that some people blush when interacting with authorities, when speaking before audiences, when becoming the centre of attention, or even when they are simply stared at by another person (Leary and Meadows 1991). Accusations of blushing mean that blushing can also be reliably induced by telling people they appear to be blushing even when they are not (Edelmann and Neto 1989).

Halberstadt and Green have further categorised the theories of blushing into Social Attention and Placation (Halberstadt and Green 1993). In the Social Attention theory (Leary, Britt et al. 1992; Darwin 1999), blushing occurs because of the "affective state and perceived presence of others." The Placation theory (Castelfranchi and Poggi 1990; Leary and Meadows 1991), on the other hand, emphasizes "the consequences that are evoked by the blush." They have carried out experimental studies utilising questionnaires and found blushing propensity has a

strong link with the propensity to embarrassment and social interaction anxiety, however, only weak correlations with appeasement and apology, which are two of the factors tested under the placation theory.

2.4.1(c) How is blushing perceived?

In our study we aimed at investigating how human participants respond towards a blushing avatar, therefore it was necessary to understand how they respond towards blushing in real life.

Due to its location and colour, blushing is a directly observable signal indicating shame or embarrassment, and therefore might appease the observer (Castelfranchi and Poggi 1990; Keltner 1995). Leary and Meadows have suggested that "blushing serves to placate others and restore normal relations after a transgression for which the person might otherwise be rejected" (Leary and Meadows 1991). This is consistent with Semin and Manstead's finding that after performing a social transgression, people who displayed embarrassment received more positive evaluation than those who did not (Semin and Manstead 1982).

De Jong's work (de Jong 1999; de Jong, Peters et al. 2003) has suggested that blushing serves a remedial function, such as attenuating the negative impression and therefore makes the observer judge the blusher's reason for blushing as less serious. His experimental studies have indicated that people who blushed after violating a social rule received less negative evaluation compared to those who did not blush. However, in this experiment only paper-based scripts were used where an embarrassing situation and the person's reaction to it were *described*. In another experiment conducted by De Jong, Peters, Cremer, and Vranken, they set up a situation where participants were instructed to "defect" in a prisoner's dilemma game and blushing was induced (de Jong, Peters et al. 2002). With the setting they intended to examine the observer's reaction. The results have however suggested a negative correlation between the Observed blush, (in contrast to the physiological blush) and the reliability attributed to the defector. This result is not only in some aspects in conflict with the previous study, but also its finding focused on the subjective "observed blushing" rather than the physiological blushing (which may have a subconscious impact on people). Most importantly, defectors' behavioural

responses differed from person to person, which introduced other variables rather than blushing. Therefore with the above experimental setting, although well-designed, it is difficult to provide substantial evidence on the effect of blushing.

As a visual cue, blushing is very difficult to test empirically with humans. One of the reasons is that it is almost impossible to "represent" blushing because it is not a facial feature that can be intentionally generated by people. However, now with character animation, blushing can be generated on avatars, and this enables the possibility of testing how participants react towards it.

2.4.2 Related work in Facial Animation

As the most closely observed area during an interaction (Argyle 1969), the face is capable of producing about twenty thousand different expressions and therefore is one of the most expressive areas of the body (Birdwhistell 1968). Facial expressions are readily recognizable by others even in a synthetic static sketch format. Many facial animation systems have been implemented, either to express human emotion (Bui 2004; Albrecht, Schröder et al. 2005) or to serve communicative functions in interpersonal interaction (Bavelas and Chovil 2000; Pelachaud and Bilvi 2003).

Among existing facial animation systems, few have included facial colouring (face turning pale or red, rosy cheeks, etc.) (Patel 1995; Jung and Knöpfle 2006). In Patel's work on digital cosmetics (Patel 1995), blushing was implemented to express the emotion of "embarrassment", where the avatar's whole face turns red with emphasised rosy cheeks. In Jung and Knöpfle's work (Jung and Knöpfle 2006) the avatar would express shame and embarrassment with blushing which covers cheeks, ears, nose, and forehead. In both works, however, no evaluation with human participants was carried out. In our work we have used a simple approach to the animation of blushing by blending two facial texture maps over time rather than an attempt at full photo-realistic rendering of blushing.

2.5 Methods of Evaluation

A Virtual Environment is usually evaluated by measuring how much presence the participants felt while experiencing it (Usoh, Catena et al. 2000; Casanueva and Blake 2001). An immersive Virtual Environment aims on creating a strong sense of

being in the virtual world with computer simulated surroundings (somewhere else) rather than the real world (where the participant actually is). In a Virtual Environment with Virtual Characters, apart from feeling being with the simulated objects, the participants should feel they are with the simulated subjects, which are the Virtual Characters. In other words, in order for the VEs to be usable and successful, they need to provide the participant with a compelling experience of being in the simulated environment (presence), and sometimes of being there with "others"(co-presence) (Casanueva and Blake 2001; Garau, Slater et al. 2003). In this Section, we first discuss the concept of presence and co-presence, and then we examine the methods of evaluation, including: questionnaire measurement, physiological data, and behavioural responses.

2.5.1 Presence and co-presence

As mentioned above, presence is usually used to evaluate a Virtual Environment and co-presence is usually used when there are Virtual Characters in the Virtual Environment. Casanueva et al. (Casanueva and Blake 2001) mention presence also as personal presence, which refers to "the psychological sensation of 'being there', having a sense of being in the place specified by the Virtual Environment rather than just seeing images present in the environment". They mention co-presence as "the feeling that the other participants in the Virtual Environment actually exist and are really present in the environment". Schroeder (Schroeder 2002) introduces presence as the sense of "being in an environment other than the one you are physically in", and co-presence as the sense of "being there together".

By definitions of presence and co-presence, there seems to be a correlation between them. Some previous studies indicate that there is a positive relation between presence and co-presence (Slater, Sadagic et al. 2000; Schroeder, Steed et al. 2001; Slater and Steed 2002). However Casanueva et al.'s experimental studies (Casanueva and Blake 2001) showed no correlation between presence and co-presence. Nevertheless, they found that more realistic (appearance) avatar generated higher levels of co-presence, and avatars having gestures and facial expressions produced a significantly higher level of co-presence when compared to static avatars. Spante et al. (Spante, Heldal et al. 2003) suggested the relationship

between co-presence and presence can vary over the whole experience, and therefore would not be adequately reflected in the results.

Held and Durlach (Held and Durlach 1992), and Sheridan (Sheridan 1992) suggested some approaches of measuring presence, including: (1) user reported sense of presence (asking the users about their sense of presence); (2) observation of user behaviours during the experiment; (3) task performance in the real and Virtual Environment (checking if a user performs a task as efficiently and in the same manner as in the real world).

For (1), users reported sense of presence can be measured with questionnaire or interview data. (2) and (3) can be measured with either participants' physiological responses, or behavioural responses including bodily movements. We discuss physiological and behavioural measurement in Section 2.5.3 and Section 2.5.4. In the following Section, we review the method of using questionnaire as a measurement.

2.5.2 Questionnaire Measurement

Questionnaires have been widely employed as the measurement of presence. The most popular questionnaires testing presence are the Slater-Usoh-Steed (SUS) questionnaire (Slater, Steed et al. 1998; Slater, Sadagic et al. 2000) and the Witmer and Singer Presence (WS) questionnaire (Witmer and Singer 1998). Casanueva et al. (Casanueva and Blake 2001) developed a co-presence (CO-P) questionnaire, in which co-presence is tested in questions such as: "To what extent did you have a sense that you were in the same place as *person y*?", and "To what extend did you have a sense of being *part of the group*?"

As a subjective method for the assessment of presence, questionnaires have limitations as it is often used with naive observers whose opinion may be biased by their prior experience or expectations, and it also differs a lot due to individual understanding of the questionnaire (Freeman, Avons et al. 1999; Slater 2004). One way could possibly eliminate or identify the difference in participants bias is to use extra personality questionnaires, and given the content of our research, questionnaires related to social anxiety.

A very popular personality questionnaire is the Revised NEO Personality Inventory (NEO PI-R, contains 240 items), or a simplified version NEO Five-Factor

Inventory (NEO FFI, contains 60 items) which examines users' personality on five dimensions: Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness (Costa and McCrae 1992). The NEO questionnaire measurement would provide a good reference in identifying participants' personality variance in experimental data analysis.

Given our interest in shyness, we are also interested in questions examining participants' social anxiety. One of the questionnaires measuring social anxiety is the Social Avoidance and Distress (SAD) questionnaire, which has 27 statements and each given either "True" or "False" as choices (Watson and Friend 1969). SAD provides a good indication on the general social anxiety level of the user; however, it does not specify different social encounters. For instance, some people may be very confident in general but at the same time very shy in front of the opposite sex. The Social Phobia and Anxiety Inventory (SPAI) questionnaire (Turner, Beidel et al. 1989), on the other hand, examines peoples' anxiety in specific interactions with: a member of the opposite sex, a stranger, a authority figure, and a group of people. Our research studies interaction between human and avatars under certain chosen social encounters so SPAI would provide us the ability to achieve a better concentration on the particular area in which we are interested, for example, anxiety in front of the opposite sex.

2.5.3 Physiological Measurement

Physiological data collected during the experimental studies offers objective evidence of participants' biological automatic responses (Slater, Antley et al. 2006). Those physiological measurements taken reveal the participants' stress and anxiety level, often including electro-cardiogram (ECG) and electro-dermal activity (EDA). The measurements for ECG are heart rate (HV) and heart rate variability (HRV), where the increase of HV and the decrease of HRV both indicate stress (Task-Force 1996). EDA measures changes in arousal through changes in skin conductance caused by sweat levels (Venables 1978; Boucsein 1992). In particular, Skin Conductance Level (SCL) indicates overall degree of arousal and the Skin Conductance Response (SCR) measures sympathetic arousal responses (Nagai, Critchley et al. 2004).

2.5.4 Using Behavioural responses in Evaluation

As introduced in 2.5.1, a common framework for understanding the response of people to their experience in a Virtual Environment is “presence” which may be defined as the extent to which participants act and respond as if what they experience in the Virtual Reality were real (Sanchez-Vives and Slater 2005). This tendency of acting realistically towards virtually generated data distinguishes VE from all other media, such as films and books leading to a range of beneficial applications from virtual psychotherapy to training. In the previous two Sections we looked at questionnaire and physiological measurements, here we look at more observable behavioural responses – participants’ actual behaviour.

Several studies have used the behaviour of participants in VE to evaluating presence (Slater, Steed et al. 1998; Slater, Sadagic et al. 2000; Slater and Steed 2002). For example, one of these studies examined the participants’ actual responses to “danger”, i.e. whether they ducked when virtual objects flew towards them (Slater and Usoh 1993).

More importantly, the interaction between human participants and Virtual Characters is of our interest and is crucial in many VE applications. In particular in therapeutic and training applications, where the involvement and behavioural response are the key factors, how the participant behaviour in the interaction is even more important than their reported “feeling” towards the Virtual Character. However, few studies have examined the participants' interactive behaviour in VEs. Using a head-mounted display delivered Virtual Reality, Bailenson et al. observed the behaviour of participants when being asked to approach virtual agents with human-like or random head movements (Bailenson and Swinth 2005). The result suggested that they showed greater hesitation in approaching the agent with more human like movement. Vinayagamoorthy et al. suggested that participants tended to adopt a socially acceptable spatial behaviour with Virtual Characters in immersive system who displayed emotions (Vinayagamoorthy, Steed et al. 2008). Friedman et al. has reported similar behaviour of users within an online 3D social environment (Friedman, Steed et al. 2007). Krämer assessed the verbal responses towards different interface and found that, when confronted with a virtual agent, the participants adopt more natural speech (Kramer 2005). These studies reflected the

importance of the use of Virtual Characters in achieving more natural interactions, as well as its limitation: in the same study of Vinayagamoorthy's, there was no difference in the distance participants maintained when different emotion (Sad, Anger) was displayed, although in everyday life it's normal to assume that people would maintain a further distance with an anger person. Another particular behaviour in human communication was also examined but failed to show in VR: in a later study of Krämer's, while interacting with a virtual agent manipulated with certain nonverbal behaviour (eyebrow movement and self-touching), no mimicry behaviour reported in the participants (Kramer, Simons et al. 2007).

In Slater et al.'s study on Virtual Reality representation of Stanley Milgram's obedience experiments, a different behavioural measurements was chosen (Slater, Antley et al. 2006). In their experiment, as part of "a learning procedure", the participants were told to inflict electric shocks to a virtual lady every time she gave the wrong answer. Apart from the questionnaire and physiological measurement, participants' waiting time before conducting each electric shock was recorded (i.e. how long they have hesitated before giving the shock). The results showed that participants waited longer when seeing the virtual lady as compared to those who interacted with the virtual lady on a text-based window, without actually seeing or hearing her. They've also found that when interacting while seeing the virtual lady, 6 participants out of 23 withdrew from the experiment before the end and none of the 11 participants in the other condition (not seeing) withdrew early.

2.5.5 Summary

Our research concerns whether people respond to Virtual Characters as if they were real, in the context of an interaction within an immersive Virtual Environment. In other words, the extent to which the participant responds towards the Virtual Character with appropriate affect. In this Section we discussed three methods of measuring participants' responses in a Virtual Environment: questionnaire responses, physiological responses, as well as examining participants' behavioural responses as a direct measure of the extent to which they respond as if the virtual encounter were real.

Most previous research on presence has used questionnaire as the measurement instrument (Witmer and Singer 1998; Slater, Sadagic et al. 2000). However, the participant can only complete the questionnaire after the experiment; therefore it only reflects what is in their memory. Moreover, as subjective responses from the participant, questionnaires also have serious methodological problems in this context (Freeman, Avons et al. 1999; Usoh, Catena et al. 2000; Slater 2004). Therefore questionnaires are best seen as supplements to behavioural and physiological data rather than the central means for assessment.

Physiological data, such as heart rate, heart rate variability and electro-dermal activity provide excellent evidence of participant's physical reaction in real time (for example (Slater, Antley et al. 2006)). However, the results are limited to a person's autonomic nervous system responses rather than higher level behavioural and cognitive responses.

Non-verbal behaviour including facial expression and bodily movements reflect human beings' automatic responses. Unlike verbal responses bodily movement is an easily observable gross overall indicator of a person's state. It therefore could offer us an additional method to assess the realism of people's responses within a Virtual Environment. Moreover, while interacting with a Virtual Character, the participants' body movement reflects not only the states of the participants themselves but also how much they are engaged with the ongoing interaction with the Virtual Character. Apart from bodily movement, other behavioural responses like "waiting time" in the virtual Milgram experiment would also provide us with an insightful approach for gathering information in the evaluation of participants' responses in VR.

2.6 The Use of VR in Psychotherapy

2.6.1 VR in Psychotherapy

Psychotherapy has been one of the major applications of Virtual Reality technology (Rizzo and Buckwalter 2001). In exposure therapy, patients are subjected to a series of stimuli that step by step increment the degree of associated anxiety – from the least difficult stimulus to the most difficult one. VR provides such stimuli in a way that is safer, less embarrassing, and less costly than reproducing the real world situations, which are often impossible to reproduce in any case. As part of a

treatment programme, a client might be placed in a Virtual Environment depicting a situation that triggers their anxiety, which is then overcome by series of gradual exposures. This has been applied, for example, to fear of heights (Rothbaum, Hodges et al. 1995), fear of flying (Rothbaum, Hodges et al. 2000), arachnophobia (Garcia-Palacios, Hoffman et al. 2002), post traumatic stress disorder(Rothbaum, Hodges et al. 2001), attention deficit disorders in the classroom (Rizzo, Buckwalter et al. 2000), and pain distraction(Hoffman, Patterson et al. 2000). The use of Virtual Reality in the successful treatment of anxiety conditions and phobias relies heavily on the extent to which patients will respond to the Virtual Reality events and situations as if they are real.

2.6.2 Using Virtual Characters in Psychotherapy

(a) **(b)**

Figure 2.3: Virtual Audience who behaves (a) positively or (b) negatively (Pertaub, Slater et al. 2002).

Although the simulation of Virtual Characters involves more complexity than other virtual objects (for instance, a virtual spider), there are evidence suggesting participants respond towards Virtual Characters even with only cartoon-like appearance and basic movements, and therefore pointing out the potential of using Virtual Characters in Psychotherapy for Social Anxiety (Sanchez-Vives and Slater 2005).

A particular area of social anxiety that has been studied in VR is fear of public speaking (Pertaub, Slater et al. 2002) where participants were exposed to static, positive, or negative virtual audiences and their reactions recorded. As shown in Figure 2.3(a), the positive audience were supportive and encouraging; they gave

positive feedbacks by nodding, smiling, learning forward towards and maintaining eye contact with the speaker. The negative audience (Figure 2.3(b)) acted disrespectfully by leaning backwards, putting their feet on the table, avoiding eye contacting with the speaker. The result showed that the negative audience had a strong effect in provoking anxiety and generating powerful negative emotions in the speaker. Such studies provide increasing evidence that people respond to such virtual social encounters as if they are real (Cornwell, Johnson et al. 2006), and that Virtual Characters can be successfully used together with exposure therapy for social anxiety (Anderson, Rothbaum et al. 2003). However, more research would be needed especially in one-to-one interactions between Virtual Characters and human participants.

2.7 Conclusions

At the start of this Chapter we reviewed facial expression and found that the face serves as a very important communication channel in interpersonal communication. Facial expressions have been studied in depth in both psychology and physiology research. Existing facial animation systems mainly serve as a communication function and an emotional expression. However, very little research has been done in evaluating facial expressions with human participants in a Virtual Reality, and an important facial features (blushing) has been left out.

We then reviewed another very important aspect of our thesis: shyness and social phobia. We reviewed the psychology background of social phobia and its connection with shyness. In the thesis we will be looking at representation of shyness so we also included the behaviours related to shyness and social anxiety. We have summarised and presented shyness related behaviours in the following categories: body, face, gaze, facial colour, voice, and other.

In the following Section we reviewed one of the most important facial features for shyness – blushing, in which we are particularly interested. The reasons being firstly, it is an additional facial cue which has not been implemented much in computer animation systems; secondly, it serves important functions in interpersonal communications; thirdly, it is something very difficult to “simulate” in a real world environment. We examined the psychological and physiological

background of blushing, which has formed a ground for our experimental design in Chapter 5.

As one of the main focuses of this thesis is the evaluation of interactions between human and avatars, in Section 2.5 we reviewed methods for evaluation. Three measurements were introduced: questionnaire data, physiological data, and behavioural responses. We presented the methods and examined their limitation.

Finally we reviewed studies that have been carried out in Virtual Reality with the purpose of psychotherapy. We learned that a well-designed Virtual Environment is able to trigger participants' automatic responses, which is the fundamental basis of our final target in using VR in psychotherapy for social phobics.

The focus of this research is experimental studies on the interaction between human and avatars. In Chapter 4, we present our first experimental study which involved a one-to-one conversation between a participant and a Virtual Character.

Evaluating Virtual Characters in VR with human participants also provides a potential method for experimental psychology and social psychology studies. Psychologists are concerned with how people interact with each other, in particular how they interpret each others' interpersonal signals during communication. One of the ways to evaluate this is to compare it with pre-recorded videos by trained actors (Gosselin, Kirouac et al. 1995). However, some human behaviour is difficult to represent by actors, such as blushing. VR in this sense may provide a better way of doing experiments where participants do actually interact with Virtual Characters which are to behave in specifically designed ways. Hence for example, Chapter 5 we study how participants respond towards an avatar who blushes, whereas it would be quite difficult to do such a study in physical reality.

In order to achieve our goal of building highly immersive interaction it is essential to build believable and responsive avatars. Before introducing the experimental studies, in the next Chapter we look into methods of animating Virtual Characters: both their facial expressions, and their body movements.

Chapter 3 Animating Virtual Characters

The main purpose of the thesis is to study the interaction between human participants and Virtual Characters. High quality animated Virtual Characters are essential in such interactions (Vinayagamoorthy, Gillies et al. 2006). In this Chapter we discuss the method of implementation for two of the most important aspects of character animation: facial expression and body movement.

The first half of this Chapter introduces our attempt to animate facial expressions which express complex mental states using motion graphs, which is based on our paper (Pan, Gillies et al. 2007). This result was not used in the following Chapters of this thesis but nevertheless contributed understanding emotional expressions and animations on Virtual Characters.

In the second half, we present the detailed procedure of using motion captured data to animate the body movement of Virtual Characters, which was used in the experimental design of the study we have conducted as described in Chapter 6.

3.1 Building Facial Animation Model with Motion Graphs

3.1.1 Introduction

Virtual Characters are an essential part of virtual worlds, because they can pass information naturally to the user by invoking their automatic physiological, behavioural and emotional responses, and therefore achieve a more empathic interaction (Vinayagamoorthy, Gillies et al. 2006). In other words, they make it easier for the user to communicate with the Virtual Environment. In an interpersonal interaction the face is the most closely observed area of the human body which conveys the richest information(Argyle 1969). Facial expression on Virtual Characters is thus an essential part of passing information more naturally and efficiently to the user.

For a very long time facial expressions have been seen as a reflection of mental states (Smith and Scott 1997). Darwin (Darwin 1993), Ekman (EKman 1992), and Izard (Izard 1971) suggested that emotions, particularly basic emotions, produce typical facial patterns. However, recently some research argues that facial expressions also function as part of communicative acts (Carroll and Russell 1996).

The basic emotions, as defined about 30 years ago by Ekman et al. (Ekman, Friesen et al. 1982) (happy, sad, surprised, disgusted, angry, and fear) are therefore no longer considered to be sufficient to explain the role that facial expressions play in communication process. Recently it has been suggested that it is important to investigate a wider range of more complex mental states, such as agreement, boredom or certainty (Baron-Cohen, Golan et al. 2004).

The work we present here serves as our first step in studying how to apply complex mental states to facial expressions of Virtual Characters. We have chosen six complex mental states to study: agreement, disagreement, concentration, interest, thinking and uncertainty. The main contribution of this work is generating complex emotions with human facial motion data using a data structure called a motion graph. The following Section discusses in detail why it is necessary to use complex mental states. In Section 3.1.3 we present related work on facial animations. Sections 3.1.4 and 3.1.5 introduce our method of extracting and applying facial expression on Virtual Characters, and generating complex mental states on facial expressions using motions graphs. Some examples are shown in Section 3.1.6.

3.1.2 Complex Mental States

A face is capable of producing about twenty thousand different facial expressions (Birdwhistell 1970). Many researchers have selected a limited set of emotional facial expressions and defined them as basic emotions, which are universally recognized emotional facial expressions. These basic emotions have been well studied since 1969 and employed in many applications (Bui 2004). However, real life communication usually entails more complicated emotions. Nowadays, with more advanced technology and the higher requirements by VR applications, research on complex mental states that go beyond the basic emotions has been carried out.

More and more VR applications require a higher level of communication through facial expressions, which may be difficult to provide with only basic emotions. For instance, communicative emotions like “convinced”, “persuaded” and “bored” are difficult to describe adequately with basic emotions. More complex mental states

are needed to provide a closer simulation of real life interactions, and therefore are able to generate more functional facial expressions, especially in communication. As an innovative method, using complex mental states in generating interactive facial expressions, could be a more flexible and efficient way to create characters in VR that bring forth realistic responses from people with whom they interact, which is the major motivation for our research.

However, in contrast to basic emotions, recognizing complex mental states requires information on consecutive facial displays rather than a static frame. Moreover, this recognition requires not only facial expression changes but also head movements. To address these problems, in this work we propose a method for modelling complex emotion facial expressions with real data from video clips of professional actors, which have been labelled with a certain emotions.

3.1.3 Related Work

There are numerous facial animation systems that display emotional expressions based on the basic emotions. These systems either display one set of the universally recognized facial expressions (Velasquez 1997; Kshirsagar 2002; Bui 2004; Paiva, Dias et al. 2004) or in addition they produce combinations of these facial expressions (Kurlander, Skelly et al. 1996; Latta, Alvarado et al. 2002; Raouzaiou, Karpouzis et al. 2003; Albrecht, Schröder et al. 2005). Recently, some applications have started to focus on the facial expressions' communicative function. Facial expressions are extremely important in interpersonal communication, providing many communicative functions such as emphasis (e.g. raising eyebrows), giving feedback as whether a listener has understood (e.g. a confused expression) and distinguishing performatives (an order can be accompanied by a frown, a request by a smile) (Poggi and Pelachaud 2000). BEAT, described by (Cassell, Vilhjálmsson et al. 2001), takes pure text as input to generate "embodied expressive behaviours". The system presented by Pelachaud and Bilvi (Pelachaud and Bilvi 2003) is integrated into a system which translates goals, beliefs, and emotions into communicative function tags through dynamic belief networks. However, these systems all present communicative signals through static facial expressions, and the facial expressions are generated based on an apriori model rather than real data.

3.1.4 Extracting and Applying Captured Data on a Virtual Character

The first step of our work is to extract the facial and head movements from video clips. Our facial expression generation framework works from head and facial displays, which are individual facial events that people use to describe facial expressions (e.g., nodding the head or smiling). Each facial display is composed of a sequence of facial actions. Several authors have suggested facial action recognition methods which learn either image-based representations (e.g., Gabor filters) or model-based representations (e.g., template matching, feature point tracking) (Pantic and Rothkrantz 2004). Of these systems, we have adopted the recognition framework proposed by (Kaliouby and Robinson 2005) to recognize head and facial displays, because it has been demonstrated to work for modelling complex mental states. Furthermore, this system uses a hierarchical representation that explicitly models facial action recognition and head & facial display recognition. This allows facial displays to be based on not just the current facial action, but also on a predetermined number of previous numbers of facial actions. Our experience shows that this works as temporal smoothing and prevents abrupt changes in the inferred facial displays.

Using the framework in (Kaliouby and Robinson 2005), a commercial face tracker is used to locate 24 landmarks on the face and track them over time. Using hand-crafted feature extractors, the movements and relative positions of these points are mapped into facial actions for 5-frame long video segments. Then, every five frames, the last six facial-actions are fed into Hidden Markov Models (HMMs) that compute the likelihood of each facial display given the recognized facial actions using a standard invocation of the Bayes' rule. The temporal filtering property of Hidden Markov Models, which are statistical models for sequential data, gives us the temporal smoothing mentioned earlier. As in (Kaliouby and Robinson 2005), the HMMs were trained using video clips extracted from the Mindreading DVD compiled by researchers at the University of Cambridge Psychology Department (Baron-Cohen, Golan et al. 2004).

The likelihoods of the facial displays, computed by the HMMs from the input video sequences, are used to drive the animation of our Virtual Characters.

We have applied facial and head animations separately. Six head action displays (head tilt, head turn, head forward, head backward, head shake and head nod) are extracted for every frame. For head tilt and head turn, the HMM out puts are simply applied on the head with corresponding axis, whereas for head forward, both “head up” and “neck forward” were applied. Similarly, both “head down” and “neck backward” were applied for head backward. On the other hand, head shake and head nod are both periodic movement, therefore a head shake motion contains two frames (head-turn-left, head-turn-right) and so as a head nod motion (head-up, head-down). Similar to head movements, the HMM outputs of three facial displays (lip pull, lip pucker, and brow raised) are applied on the Virtual Character as morph targets for each frame. Table 4.1 lists the head and facial movements name with their descriptions.

Table 3.1 Head and Facial displays and their Description

	Head and Facial Displays	**Description**
Head & Neck Movements	Head Turn	head-turn
	Head Tilt	head-tilt
	Head Forward	head-up + neck-forward
	Head Backward	head-down + neck-backward
	Head Shake	Alternately head-turn-left, head-turn-right
	Head Nod	Alternately head-up, head-down
Facial Movements	Lip Corner Pull	lip corner pull (AU12)
	Lip Pucker	lip pucker (AU18)
	Eyebrow Raise	eyebrow raise (AU1 + AU2)

3.1.5 Animating Complex Mental States with Motion Graphs

As described above complex mental states differ from basic emotions in that they cannot be effectively recognized from static facial expressions, only from facial movements over time. This implies that we must use different animation techniques, ones based on time series rather than static methods such as morph targets or principal component analysis.

The approach we take in this work is to base our animations on a corpus of capture facial motion data using motion editing method to generate new animations

from this data. In particular we use a data structure called a motion graph (Kovar, Gleicher et al. 2002). A motion graph enables new animations to be generated from a corpus of animation data by re-sequencing animation clips in different orders as shown in Figure 3.1. It is a directed graph structure in which edges are motion clips and nodes are possible transition points between clips. These transition points are chosen so that they ensure smooth transitions between different clips. Thus any walk of the graph will generate a new animation without any unrealistic breaks. This animation is composed of a sequence of sub-clips of the animation data.

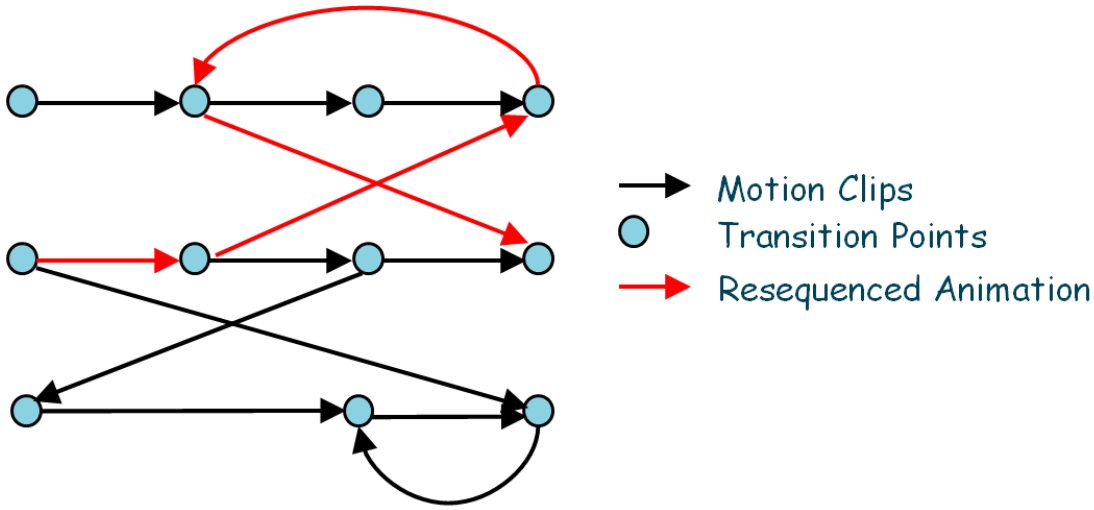


Figure 3.1 Motion Graphs

The motion graph is constructed automatically from data as suggested by Kovar et al. (Kovar, Gleicher et al. 2002). Nodes are chosen by finding points in the original motion data that are similar enough that smooth transitions can be automatically created.

This requires some measure of the difference between two frames in a piece of motion data, such that two frames with a low difference make a good transition point. We have adapted the measure suggested by Lee et al. (Lee, Chai et al. 2002), so that it handles action unit data as well as joint rotations.

Once constructed the motion graph can be used to generate new animations that display complex mental states. A new animation is created by walking the graph. We must choose a graph walk that gives a good representation of the desired mental state. The simplest method would be to choose, at each node, an outgoing

edge that comes from motion data that represents the desired emotion. However, when there are no such edges, the best policy is to choose an edge that leads to a portion of the graph that contains many nodes with the desired emotion. We therefore assign a value to each edge that both represents the immediate suitability for each mental state and the suitability of the nodes it leads to. When generating new animations we choose the edge that has the highest value. The value is found by solving a Bellman equation for the graph.

The Bellman equations link the value of an edge, both to its immediate value (whether the edge itself if suitable) and its expected future value (whether the edges it leads to are suitable). The value, $V_{i,e}$, for edge *i* and emotion *e* is calculated by iteratively solving the following Bellman equation:

$$V_{i,e} = V^0_{i,e} + \gamma \max_{j \in children(i)} V_{j,e} \qquad (3.1)$$

Where $V_{i,e}^{0}$ is 1 if the endpoint of edge *i* comes from a motion clip that represents emotion *e* and 0 otherwise. The parameter γ ($0 < \gamma < 1$) is a fall-off value which ensures that the values of future edges weighted lower than current edges.

3.1.6 Results

Six communicative complex mental states are chosen and implemented: agreement, disagreement, concentration, interest, thinking and uncertainty. We use 3 videos for each emotion, from Mind Reading, a computer-based guide to emotions (Baron-Cohen, Golan et al. 2004). We first extract the captured data of each video clip, and then applied this on the Virtual Character. From this data we create a motion graph including the six emotions. Finally, we animate each of the six complex emotions separately with in total 18 video clips.

Figure 3.2 is an example from the second step as described in Section 3.1.4: applying captured data to the Virtual Character. The emotion of this example is *undecided*, which belongs to the emotion group: *uncertainty*.

Figure 3.3 and 3.4 are examples of our final results. Each of them is created by 3 different video clips, but within the same group, using motions graphs. Figure 3.3 is from the emotion group uncertainty and Figure 3.4 is from the emotion group interest.

Figure 3.2: Applying captured data to the Virtual Character. The 4 images on top are from the original video of undecided, which belongs to the uncertainty group. The 4 images below are the generated animation for this video clip, where the Virtual Character has the similar head and facial movements, which convey the same emotion: undecided.

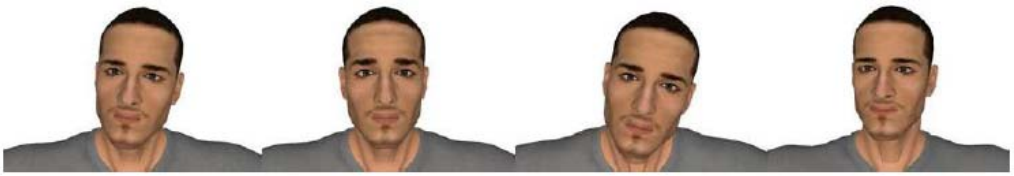


Figure 3.3: Animation result of the emotion uncertainty

Figure 3.4: Animation result of the emotion interest

3.1.7 Conclusions and Future Work

This is an ongoing work to extend the breadth of expression possible in facial animation systems. We have done this by using complex mental states that go beyond the limited set of emotions commonly used in facial animation. In order to model the subtleties of these mental states, we have based our method on real human facial movements captured from video sequences. In this method, six head

action features and three facial action features are considered. The final results are new animations created with motion graphs for each chosen complex mental states.

We have shown some initial results of our work that indicate the viability of our method. The use of an animated representation enables us to display mental states that would not be visible with static expressions. However, these results are preliminary, and more work is needed to obtain completely faithful representations of the mental states. One of the drawbacks of our current implementation is that the range of expressions that can be captured from the videos is limited. This is because the facial expression recognition system we use, though well adapted to complex mental states, is primarily designed for classification rather than motion capture. In future work, we would like to extend the number of facial displays we recognize, for example adding displays such as mouth open, teeth showing. Another problem is that asymmetric facial expressions are not recognized, thus limiting the expressive potential. Addressing these short comings will greatly improve the output of our method.

However, because of these limitations, the resulting facial expressions were not satisfactory. For this thesis, this work serves as an exploration into the implementation of facial expressions using a machine learning method. It helped us understand complex emotions and gaining practical experience in the implementation of facial expressions. This has benefited our design and implementation of subsequent studies.

3.2 Representing Shyness through Body Movements with Motion Captured Data

In the previous Section we presented our implementation of realistic facial expressions. In this Section, we look at another very important aspect in avatar animation – body movement. Here we present the detailed implementation procedure of using motion captured data to animate the body movement of Virtual Characters. Our description follows the procedure of an implementation which was part of an experimental design (presented in Chapter 6). In the experiment we evaluated participants' reaction towards a shy virtual woman who expressed her shyness through her body movements. Here first we review the relationship

between shyness and bodily movements, then give the technical detail of the design following the chronological procedure of the implementation: motion capture, applying the motion capture data to the avatar, and finally controlling the avatar in the CAVE-like System with PIAVCA (Platform Independent API for Virtual Characters and Avatars) (Gillies, Pan et al. 2008) and XVR[1] (Extreme Virtual Reality). This Section serves as a technical reference for a future implementation, and also provides information for researchers interested in following a similar approach. Even though we provide a specific example from our experimental design, we also give general information on related technical detail based on our experience.

3.2.1 Shyness and Bodily Movements

Bodily movement plays a significant role in human communication. Unlike facial expressions, which very often are deliberately delivered when they serve as party of communicative act (Bavelas and Chovil 1997; Pelachaud and Bilvi 2003), body movements are more often the "emotional leakage" which reveals the personality of a person (Argyle 1975; Knapp and Hall 1978).

Table 3.2: Shyness related Body Movements

Area	**Shyness related behaviour**
Hands	Extraneous hand movement, hand tremors, hands restrained
Arms	Extraneous arm movement, arms rigid
Legs	Knees tremble
Feet	shuffles feet
Posture	Stiff posture
Whole body	More body motion, paces, sways

In this work we are interested in representing shyness by applying body movements to Virtual Characters. In the previous Chapter (Section 2.3.3) we reviewed behaviours that are directly associated to shyness, embarrassment, or social anxiety, among which many are related to the body. As shown in Table 3.2, shyness could be expressed over the whole body, from shuffled feet to restrained

[1] http://www.vrmedia.it/

hands, from the detailed trembling fingers to the whole stiff posture. Although bodily movement does not represent the whole picture of being shy, it does cover many expressions of shyness.

3.2.2 Express Shyness through Motion Capture Data

To be able to express shyness on the body movement we used professional actress and motion captured data in our study. Using motion captured data in computer character animation was originally developed in the 70's, and has become popular in recent years (Sturman 1994). In motion capture animation, actor or athletes are used to produce movements which are recorded with infrared camera or other motion capture technologies. These movements are then altered or directly applied to Virtual Characters. This technology is widely used in films (for example, Beowulf[2], The Polar Express[3]) and computer games (GTA[4], Mass Effect[5]).

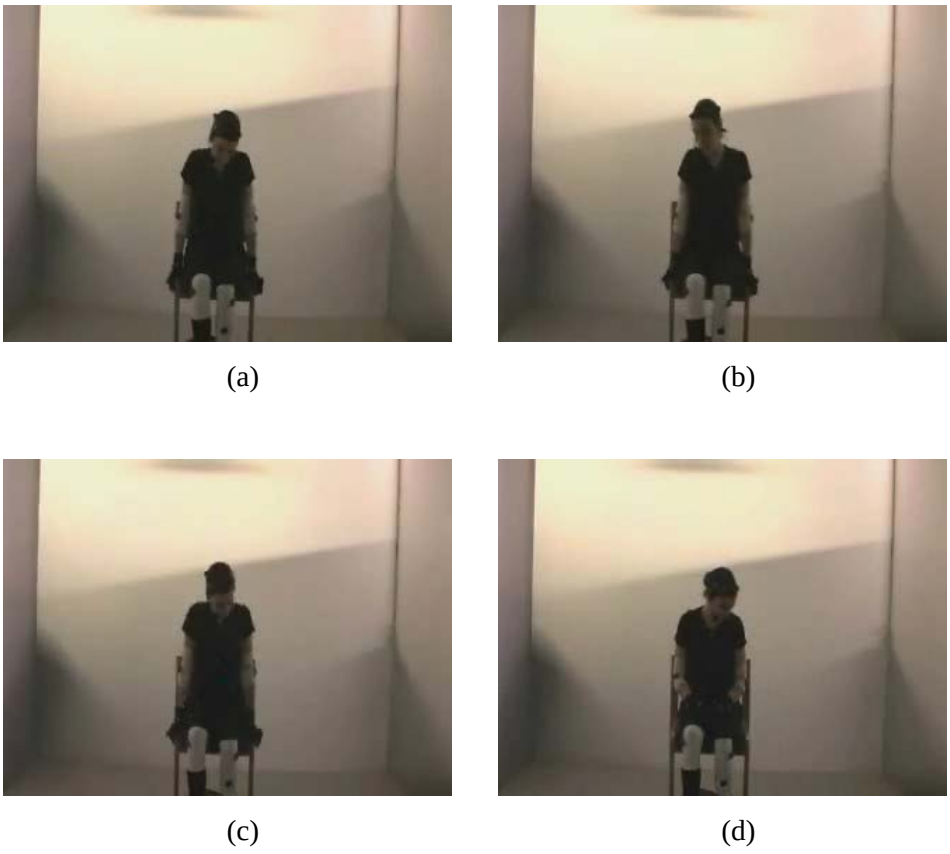
One of the reasons that using motion captured data for character animation was so popular could be it represents human beings' natural movement with the full detail. Another advantages of using motion captured data rather than hand animation is the voice could be recorded at the same time. Therefore the voice and the body movement are well synchronized.

As part of the experimental design for work presented in Chapter 6, motion capture was the core procedure of our implementation. There were two conditions in our experimental design (see Chapter 6), in condition 1 participants interact with a very shy avatar, and in condition 2 (control condition) the avatar behaved confidently. In both conditions the same script was used, and thus the personalities (shy or non-shy) were expressed through the avatars' nonverbal communication: body movement and the nonverbal cues of the voice. Therefore the motion capture for the body movement was crucial for our experimental design.

Our formal motion capture recording was performed on the 11th of May, 2009, with a professional actress who had many stage experiences. She was given the script for our recording to prepare in advance. Upon arriving, we instructed her

[2] http://www.beowulfmovie.com/
[3] http://polarexpressmovie.warnerbros.com/
[4] http://www.rockstargames.com/grandtheftauto/
[5] http://masseffect.bioware.com/me1/

regarding the technical details and the purpose of the experiment, and went through the script with a participant, following which we had a brief discussion on behaviours related with shyness. When the actress was ready for the real session, we started the motion capture with our Vicon[6] motion capture system. Thirty-two markers were used to capture her movements (for a list of markers please see Appendix A). During the capture for the first condition, she was told to act as if she were very shy and anxious, as shown in Figure 3.5 (a) – (d). As a contrary, she behaved very confident and aggressive in the second condition (Figure 3.6 (a) – (d)).

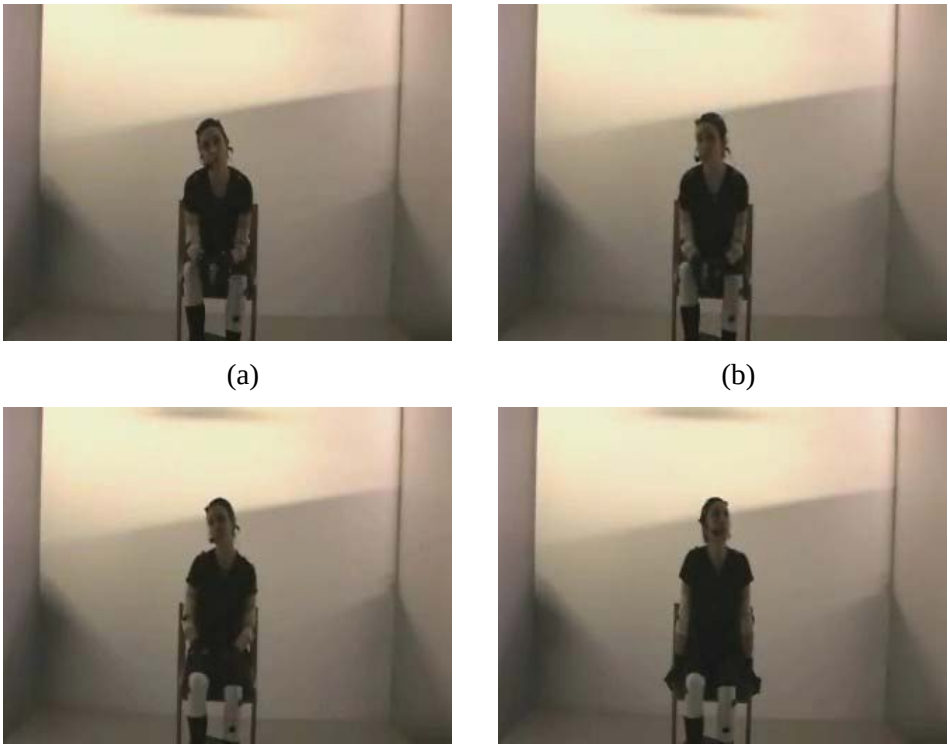


(a) (b)

(c) (d)

Figure 3.5: Motion Capture Shy Condition (a) – (d) The actress acted through her body movements as if she was very shy, by lowering her head, displaying a stiff posture and frequent movements.

[6] http://www.vicon.com/



(a) (b)

(c) (d)

Figure 3.6: Motion Capture Non-shy Condition (a) – (d) She displayed more aggressive and confident behaviours as a contrary of the pervious condition.

After the motion capture session, we have reconstructed the animation with the ViconIQ software. This procedure mainly includes labelling the markers and retrieving the markers which were lost during the capture (for instance, markers that were obstructed from the camera).

3.2.3 Applying Motion Captured Data to Avatar

A photo-realistic female Virtual Character originally created using the Poser[7] system was chosen for our study. We exported the mesh of the avatar and the appropriate clothing and hair style from Poser to 3dsMax[8], using GestureMax[9]. The complexity of the mesh directly imported from Poser can be over 300,000 polygons, which is very heavy for real time rendering. In our case some details of the mesh

[7] http://store.smithmicro.com/default.aspx
[8] http://www.autodesk.co.uk/
[9] http://www.digimation.com

were unnecessary. Therefore we reduced the some part of the mesh including trousers, clothes, and arms.

After importing the mesh to 3dsMax we performed rigging, which defines the link between the mesh and the biped (provided by 3dsMax). Then we imported our motion captured data to the biped. The biped was then animated.

Generally the animated biped requires further adjustments. Ideally the movements of the animated avatar should be exactly the same as the actor, however in reality this is normally not the case. This is because first, the avatar would not have exactly the same body as the actor who performed the motion capture; secondly, the rigging of the character would not be perfectly representing the reality; finally, the motion capture reconstruction would not represent the exact movement of the actor (due to missing markers, change of position of the markers during the capture, etc.). For the above reasons, the animation would the best be the approximate representation of the movement rather than something precisely. Most of the time the animation is good enough to represent the actual movement, but there can be problems. The biggest problem would be the avatar's hands or fingers occasionally clipping the avatar's body, which is physically impossible in real life and may perturb the participant in a realistic interaction in VR. The method to remove such flaw would be to adjust the animation by hand, adding another layer of animation. This method could also be helpful if it's needed to re-adjust either the rotation of the avatar's head or the position of the centre of mess (i.e. re-position the avatar in the environment).

3.2.4 PIAVCA and XVR

In our experimental design, we used PIAVCA to edit our final animation and XVR for the design and supporting our Virtual Environment in the CAVE-like system. The avatar followed a pre-defined script and interacted with the participants in real time. For each utterance on the script we prepared an "event" in the experiment which contains both voice and correlated body animation. Apart from utterance from the script, we also included events for the avatar to walk in and sit down, or stand up and leave the room. During the experiment, all events were displayed on a control panel (see Figure 3.7). The real time interaction was achieved through the

triggering of appropriate events from this control panel by an experimenter who was listening to the interaction. A similar method (triggering events with control panel) was also used in our experimental study described in Chapter 4.

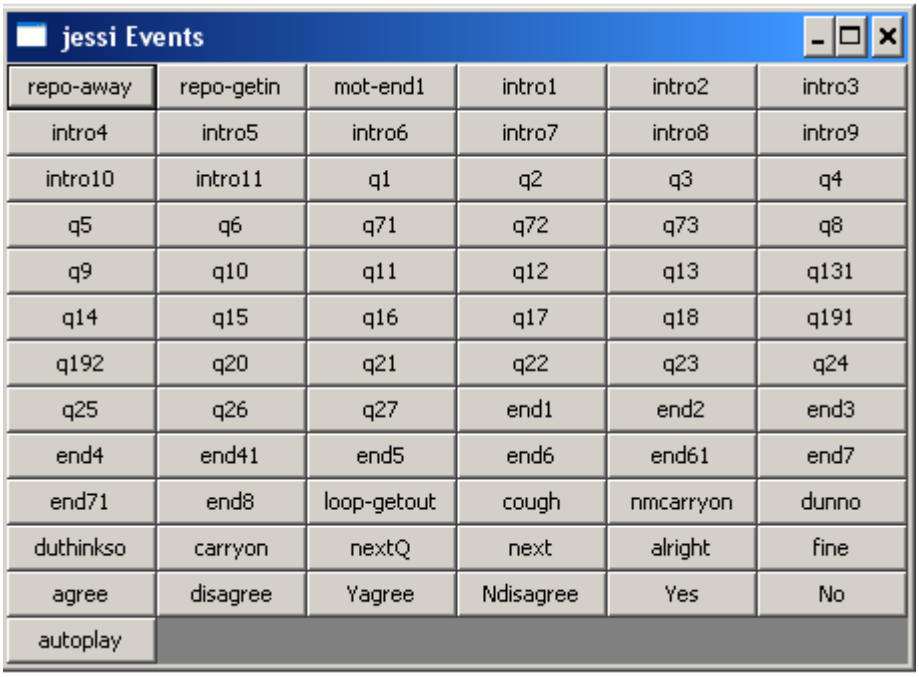


Figure 3.7: Events on a control panel to be triggered during the experiment to achieve real time interaction.

In preparation of each “event”, we loaded the avatar and the related animation file in PIAVCA. Then with PIAVCA we defined each event as an “override motion” with the voice file and the corresponding “SubMotion” from the big animation, as shown in Figure 3.8., which could be edited either in the text file or with PIAVCA Designer (see Figure 3.9). In the end the animation by PIAVCA and the scenario created with 3dsMax were both loaded with XVR, then run in the CAVE-like system. Figure 3.10 demonstrate the final implementation in XVR on a desktop.

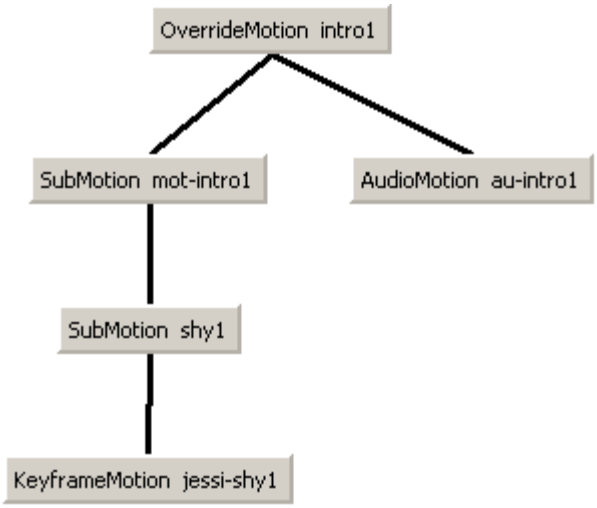


Figure 3.8: The structure of an event implemented with PIAVCA, which contains an audioMotion and a corresponding SubMotion.

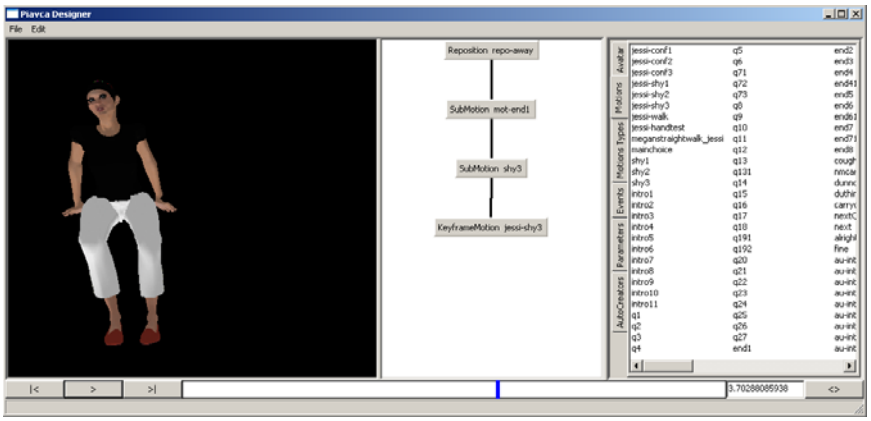
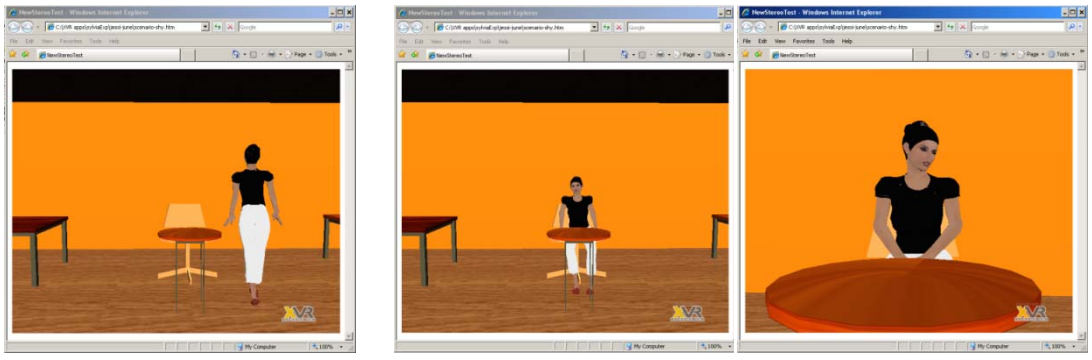


Figure 3.9: PIAVCA Designer



(a) (b) (c)

Figure 3.10: XVR on a desktop. (a) Avatar walks in to the scenario, (b) sits down, and (c) during the interaction she behaves shyly.

3.2.5 Conclusion

In this Section we presented our method for representing shyness through body movements of a Virtual Character, as well as a step-by-step description of using motion captured data on Virtual Characters in a CAVE-like system. In our approach, the representation of shyness relied on the actress' interpretation of shyness and her ability in delivering it. Although we have reviewed behaviours related to shyness with psychological literature and had a discussion with the actress about our findings, we did not want to emphasise our understanding of shyness to the actress and restrict her acting with any guidance. Instead we were more interested in using the experience and performance from a professional actress in expressing shyness.

The final animation was evaluated in our experiment described in Chapter 6. The results of the experiment show that the interaction with the animated avatar was highly immersive and many participants reported that they have responded towards her automatically. However, some participants complained that there were no facial expressions or eye movements. In our future studies, we will look into recording facial expressions with motion the capture system and combine them with body movement data, as well as add gaze and other features that are essential for human communication.

In this Chapter we introduced our method in implementation of facial and bodily animation. In the following Chapter, we move on to experimental studies where we investigated the interaction between human participants and a forward female avatar in a CAVE-like system.

Chapter 4 Experiment: Real Man Meets Virtual Woman

This Chapter describes the design and study of a Virtual Environment experimental scenario setup in a CAVE-like system, part of the content has been published in two papers (Pan and Slater 2007; Pan, Gillies et al. 2008). It serves as our first step to investigate the interaction between Virtual Characters and people. In particular, it is part of our study on whether people with Social Phobia react with expected anxiety to Virtual Reality depictions of social encounters.

4.1 Motivations

As introduced in Chapter 2, people with social phobia suffer from an irrational anxiety in social performance situations. This anxiety interferes with their everyday life and makes it more difficult for them to pursue professional success and relationships. The fear of interaction with other human beings stops them from engaging in social encounters, creating a downward spiral effect which further impairs their social ability. Our question is the extent to which people will respond with appropriate affect to virtual social encounters: for example, will males who are normally shy or who usually avoid encounters with women react with anxiety, and will males who are socially confident enjoy the encounter? Moreover, a particular trait of social phobia is that individuals become particularly anxious when they feel that they are being observed by others in a social situation. We therefore also include in our study a factor where the social encounter between the real male and virtual female may be the subject of attention, or not, by other virtual humans who populate the bar scenario.

4.2 Hypothesis

Our goal is to test the hypotheses that (1) socially anxious males will at first experience anxiety when approached by the virtual woman, but eventually become more relaxed because she takes the initiative as she keeps the conversation going; our subsidiary hypothesis is that (2) those socially anxious males who are frequently looked at by the other Virtual Characters will exhibit greater anxiety than those in the condition where the other characters do not pay attention.

4.3 Experimental Design

4.3.1 Materials

To provide the participants with an immersive interactive environment, the experiment was conducted in a CAVE-like projection based system (Cruz-Neira, Sandin et al. 1993) – the specific system being a Trimension ReaCTor. This has three back-projected vertical screens (front, left and right) (3m×2.8m) and a floor screen (from a ceiling mounted projector) (3m×3m) controlled by a Silicon Graphics Onyx 2. The back of the CAVE-like system is an open place. In this particular study we were interested in the anxiety of the participants that might be triggered by the Virtual Characters. Therefore a heavy black curtain was settled up and closed during the experiment to avoid the participant being too aware of the experimenters.

The participants wore 3D stereo glasses (Crystal Eyes, Stereographics) which are shutter glasses in sync with the screen displays that are refreshed at 45 Hz each eye. The fusion of left and right images creates a stereo view. The participants also wore a head-tracker (Intersense 900), that tracks the position and orientation of the head so that the computer refreshes the displays according to head orientation and position, thus allowing the creation of head-movement parallax. The captured tracking data are also used to generate gaze and proxemics in real-time, for detail please refer to Section 4.3.2.

To assess the participants' physiological reactions during the experiment, the participants were fitted with a ProComp Infiniti (Thought Technology) physiological recording device that records ECG (256Hz), EDA (32Hz) and respiration (32Hz). Electrodes were placed on the palmar areas of the index and middle fingers of the left hand in order to record electrodermal activity. Electrodes were placed on the left and right collar bones and the lowest left rib in order to record ECG. The ProComp chest strap was used for recording respiration. The experiment was conducted over several days from August to November 2006 in the Virtual Reality Laboratory at University College London. The temperature of the VR Laboratory is maintained at a constant level by air conditioning.

4.3.2 Scenario

(a) (b) (c)

Figure 4.1: The Scenario: (a) the Virtual Character first looks at the participant and then (b) approaches him and (c) a conversation ensues while the other characters continue their conversations.

The scenario was a virtual bar populated by 5 Virtual Characters 4 of whom are talking to one another, except for one lone female, 'Christina'. Once the participant enters the scenario Christina begins to stare at him for a few seconds (Figure 4.1 (a)), then makes her way towards him (Figure 4.1 (b)), and then initiates a conversation (Figure 4.1 (c)). It is important to note (as shown in Figure 4.1 (c)) that from the point of view of the participant Christina is life-sized and that the projection is active stereo. The participant stood approximately in the centre of the room and head tracking was used so that Christina could look at him in the eyes, and also the other characters in the room would occasionally look towards him.

Christina is modelled to be an attractive female, speaking English with a slight Portuguese accent (the accent of the real actress who recorded the script). She started the conversation with the participant by introducing herself and asking the participant questions. When he spoke, she appeared to listen carefully and showed her interest by nodding and smiling. She also showed her interest by leaning forward to him, smiling, looking at him, and also by breaking the norms of social distance (of the country in which the study was conducted) by approaching within 0.5m. If the participant asked where she was from, she told him that she is an air hostess and had just arrived in London. Finally she suggested they should meet up again. The whole conversation lasted about 10 minutes. The detailed interaction is shown in Table 4.2.

Christina's behaviour consisted of a number of multi-modal utterances, containing recorded speech, body and facial animation, which were triggered from a control panel by an experimenter, who was listening to the experiment out of view of the participant. There were around 60 utterances prepared and pre-recorded; half of these are the core of the conversation and the rest of them are backups for unexpected situations. Each utterance is a synchronised combination of speech (audio file) and movements (animation). Our animation engine distinguishes between foreground behaviour, the multi-modal utterances, and background behaviour. Background behaviours are behaviour patterns that happen continuously, and in parallel with any utterances, either for the whole scenario or parts of it. They are vital in providing a sense of life and believability to the character. We use two background behaviours: gaze and proxemics. We simulate character gaze behaviour using a model of gaze for conversation (Vinayagamoorthy, Garau et al. 2004). We use a model of proxemics that ensures that Christina mostly orients towards the participant and maintains an appropriate conversational distance, but breaking this as time goes on as she gets closer. The following is an extract from a typical conversation (the full script see Appendix C): (Christina – C; Participant – P)

C: This shirt looks great on you, how much was it?

P: Thank you! It is a gift.

C: Ah, I really want to find a pair of trousers something like those for my brother (glancing down at the man's trousers). Where did you get those?

P: Haha, I cannot remember, but there are a lot of nice shops alone the Oxford Street if you are interested.

C: s So, Do you know anyone here?

P: Well, not really anyone else, no.

C: I feel a bit shy about talking with the other people, do you mind if I talk with you for a bit longer?

P: Sure, no problem.

4.3.3 Factorial Design

Table 4.1: Factorial Design.

	Other Virtual Characters looking at the participant	**Other Virtual Characters NOT looking at the participant**
Shy Participants (Anxious)	6	6
Confident Participants	6	6

As shown in Table 4.1 the experiment is a 2×2 between-groups factorial design. The first factor is whether the participant experiences social anxiety in everyday life or whether he is socially confident. This was determined by a adjusted version of Social Phobia and Anxiety Inventory (SPAI) questionnaire which is a set of the original SPAI questionnaire (Watson and Friend 1969). There are 36 questions in our adjusted-SPAI questionnaire. In SPAI, there are 21 questions explicitly related with the anxiety towards interacting with the opposite sex. Each question has an "anxiety" scaled ranging from 1 to 7 (as when the participant chooses the answer from "never" to "always"). We selected 8 questions out of 21 which are related what the participant was going to experience in our experiment. For example, 3 of these questions are:

- I feel anxious in a bar or restaurant with opposite sex.
- I feel anxious and I do not know what to do in a new situation with opposite sex.
- I feel anxious when approaching and/or initiating a conversation with opposite sex.

We also included one additional question which is particularly suited to our scenario ("I feel anxious when being approached by opposite sex"). We also include another 27 questions to avoid letting the participant realize what we were trying to test. Please see Appendix C for questionnaires used in this study. The sum of the anxiety score of the 9 questions indicates if the participant is shy or confident towards the opposite sex. We decided to choose the lowest 30% percent as socially confident and the highest 30% as shy participants.

The second factor is the extent to which the other Virtual Characters in the bar stare towards the participant. In one condition once the conversation has started the other characters do not look towards the participant, and in another condition they do look frequently. Our interest is to discover whether social anxiety is increased for those participants who become aware that they are being observed by the others.

4.3.4 Response and Explanatory Variables

We measured three classes of response variables: questionnaires and post experiment interviews, physiological data, and participants' behavioural responses during the experiment.

Two questionnaires were used to measure participants' subjective responses after the experiment: standard measures of presence (SUS, see Section 2.5), and post-SPAI which measures participants' social anxiety in response to the interaction in the CAVE. The post-SPAI questionnaire was based on the adjusted-SPAI (or pre-SPAI), and it includes questions related to participants' general anxiety towards the interaction in the CAVE, as well as how anxious they felt because of the female avatar.

In the physiological measurements we included ECG and EDA (see Section 2.5), which were recorded during a 2.5 minute baseline period and subsequently throughout the experimental session. During the baseline the bar scene was displayed without virtual people, though there was background music. Participants were asked to stand still during the baseline. We were particular interested in how these measures changed during the course of the experiment, and varied across the conditions in comparison to this baseline recordings during a relaxation period prior to the main experiment.

Participants' behavioural responses were also of interest and we have recorded the whole interaction in the CAVE with a video camera from behind the participants.

4.4 Procedure

4.4.1 Recruitment

Recruitment was by advertisement throughout the UCL campus and by UCL-wide emails. The experiment was approved by the UCL Ethics Committee, and involves fully informed consent. Subjects were paid £5 for their participation.

The pre-SPAI questionnaire was put online and we have advertised the link through emails and posters on the campus at UCL. Sixty-three people filled in the online pre-questionnaire, 28 participants were invited and attended our studies. Eventually 4 were eliminated: 2 of them are over 50, the system failed in the experiment for one participant, and another participant explained to us that he is homosexual so the scenario was too disturbing for him. Thus eventually we have 24 valid participants, 6 for each group. The mean age was 25$\pm$11 (from 18 to 36) years with no significant difference within the 4 conditions. All participants were males. 6 of them were undergraduates, 6 Master students and 8 PhD students. The rest were 1 faculty, 1 university staff, 1 lawyer and 1 office worker. They were all fluent in English.

4.4.2 Procedure

Participants attended the experiment at pre-arranged times. Each participant was provided with an information sheet, and given a consent sheet to sign if they agreed to do the experiment. Each was also asked to fill in a pre-questionnaire giving basic information such as age, occupation, etc. Then he was introduced into the CAVE-like system and fitted with shutter glasses, a head tracker and the ProComp Infiniti physiological recording device, and a microphone in order for the experimenter to hear the conversation. A 2.5 minute baseline recorded participant's physiological responses while they were standing still in a relaxed state, and the background music was playing. This was then followed by the actual experiment, which took about ten minutes. Table 4.2 shows the sequence of events and avatar questions in the experiment. Then participant was required to fill in the post-SPAI questionnaire and the SUS presence questionnaire. Finally a short interview was held. The whole procedure took between 45 and 60 minutes. The experimental

operator and an assistant were there throughout the whole experiment; both of them were females.

Table 4.2: Sequence of Events and Avatar Questions in the Virtual Encounter

1	Baseline starts
2	Baseline ends
3	Experiment starts
4	Avatar stares at the participant
5	Avatar approaches to within normal social distance
6	“Hi, It looks like we are the only people alone here, right?”
7	“My name is Christina.”
8	“It's very nice to meet you.”
9	“So, what are you doing for a living?”
10	“Very interesting, tell me more.”
11	“I'm an air hostess; I just arrived in London yesterday. Where do you live?”
12	“I don't know London very well, but actually, I am thinking about moving here, what do you think?”
13	“But I heard it rains all the time here, is that true?”
14	“Well, the weather is not that important to me. Have you lived here long?”
15	“Do you like it here?”
16	“I've noticed that people dressed very well around here. By the way, that shirt looks great on you. How much was it?”
17	“Ah, I really want to find a pair of trousers, something like these (Looking down) for my brother. Where did you get these?”
18	“So, do you know anyone here?”
19	“I feel a bit shy about talking with other people, do you mind if I talk with you for a bit longer?”
20	The avatar approaches to an intimate distance
21	“If you don't mind me saying, I think you look very nice.”
22	“I was wondering actually, are you single, or involved with someone at this time?”
23	“Maybe we should meet up.”

4.5 Results

As mentioned in 4.3.4, we have collected 3 categories of data: subjective results include questionnaires and post experiment interviews, physiological recordings of ECG and EDA, and observations of behaviour during the experiment.

We first present the mean of post-SPAI score, which is participants' self-reported general anxiety during the experiment. We also compare post-SPAI with their pre-SPAI score which shows their everyday life social anxiety level in general.

For physiological data we have measured ECG (HR and HRV) and EDA (SCR and SCL, see Section 4.3.4). Unfortunately a significant part of the EDA and ECG data was lost due to equipment failure. In Section 4.5.2 we present a brief analysis with the available data.

In Section 4.5.3 we present our analysis on participants' behaviour during the experiment. In particular, we look at their body movements associated with social anxiety (for example, frequently shifting weights reflects high anxiety level), as well as their behaviours related to certain events: we want to see if their reaction was similar to a real life situation towards those certain events (for example, when the avatar asked about the participants' clothes, if they looked down at their clothes).

In the end we present some selected comments left by the participants regarding their experiences.

4.5.1 Questionnaire Results

Table 4.3 shows the mean post-SPAI scores (participants' general anxiety during the experiment) for each cell of the design table. The results suggest that those in the Anxious group tended to have a greater anxiety response than those in the Confident group, and for the Confident group there was greater anxiety as a result of being observed.

Table 4.3: Mean and Standard Deviations of post-SPAI scores (n = 6 observations per cell)

	Not Observed	Observed
Confident	1.68 ± 0.28	2.76 ± 1.42
Anxious	3.49 ± 0.90	3.20 ± 1.41

However, Figure 4.2 shows a possible reason for this, which is the differential response to being looked at between the Anxious and Confident groups. For the Anxious group it seemed to make no difference – perhaps because their anxiety was already high, and being watched was of marginal importance. However, for the Confident group there is some evidence that those who were being observed had higher tendency to anxiety than those who were not being observed, though this may be due to one outlier.

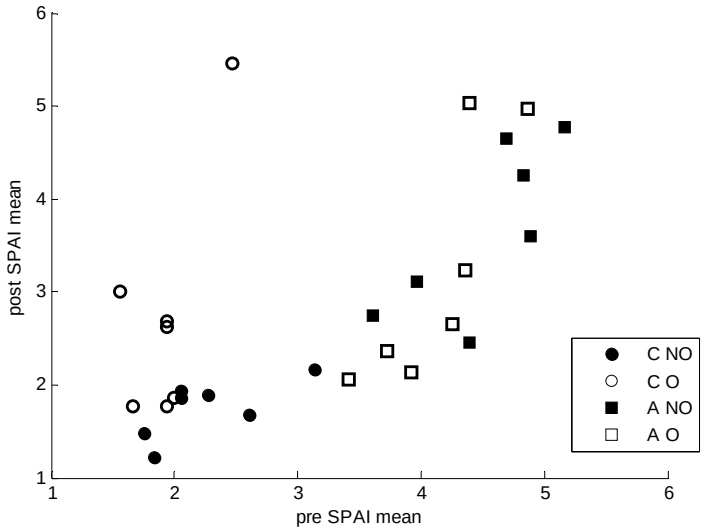


Figure 4.2: post-SPAI mean against pre-SPAI mean by anxiety and observation factors: C NO: Confident participants, not observed; C O: Confident participants, observed; A NO: Anxious participants, not observed. A O: Anxious participants, observed.

Retaining the possible outlier a two-way analysis of variance rejects the hypothesis that the mean post-SPAI is equal between the Confident and Anxious group (P=0.0211) but does not reject the hypothesis of equal means between those who were observed and those who were not, and there is no interaction effect. A Jarque-Bera test does not reject the hypothesis of normality of the residuals (P=0.10). If we exclude the extreme point, then a two-way analysis of variance similarly rejects the hypothesis of equal mean post-SPAI between the Confident and Anxious groups (P = 0.0016) and there are no other significant effects. Again the hypothesis of normality of the residuals is not rejected (P = 0.35).

If we treat pre-SPAI as a covariate and retain the extreme value, then the Analysis of Covariance result (treating the main effects as binary variables) is shown in Table 4.4, which corresponds well to the result seen in Figure 4.2.

The analysis of the questionnaire data therefore suggests that for the Anxious group their anxiety response to the virtual woman was positively associated with their normal level of social anxiety in everyday life, and independent of whether or not other Virtual Characters were looking at them.

Table 4.4: Analysis of Covariance Group (confident = 0, anxious = 1) Observed (no = 0, yes = 1) R^2 = 0.67, F=13.24, P = 5.47×10-5 d.f. = 20. The hypothesis of normality of the residual errors is not rejected (P = 0.86).

Variable	Estimate	P
Constant	-0.4938	0.3766
Group × Observed	-3.4542	0.0009
preSPAI	0.9181	0.0000
Observed × preSPAI	0.8296	0.0007

4.5.2 Physiological Data Analysis

Both EDA and ECG were recorded for the experiment. EDA data was available for 14 of the 24 participants, and from the ECG recording only 12 participants were available. Therefore we treat this result as a pilot study, and here we present the analysis on SCL with the existing data.

We first consider mean event-related SCL for the combined group of 14 participants. Figure 4.3 shows plots of the means over all n=14 of 10s segments around each of the events. It can be seen that the one that reaches the highest peak is for the event when the avatar violates the norms of social distance approaching the participant very closely (curve 20).

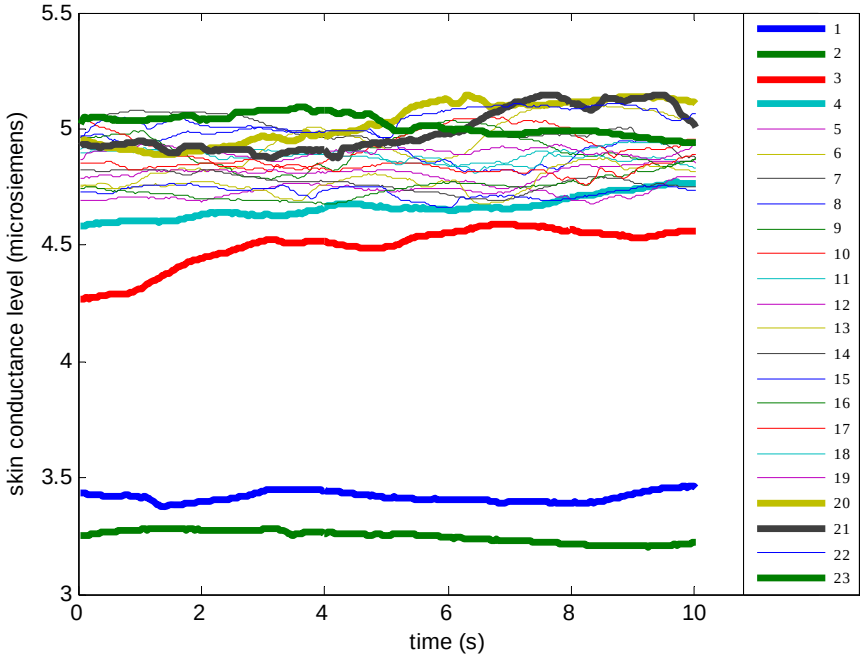


Figure 4.3: Event Related Mean SCL. The mean SCL over n=14 participants is taken in a 10s window after each event, except that for the end of the baseline the sequence starts 10s before the end. The highlighted curves are (2) the last 10s of the baseline, and the remainder are 10s from the start of: (1) the baseline, (3) the start of the experiment, (4) when the avatar first initiates contact by gazing at the participant, (23) the avatar says "Maybe we can meet up afterwards", (21) "If you don't mind me saying, I think you look very nice" (22) "I was wondering actually, are you single, or involved with someone at this time?" (20) When the avatar violates normal social distance and approaches the participant closely.

Figure 4.4 shows another way of looking at the same data with box plots for each of the 10s sequences for each event. It is clear that the highest median is for event 22 ("I was wondering actually, are you single, or involved with someone at this time?"). Note the generally lower values of the SCL for the ordinary topics of conversation (questions 12-16) and then the general increase as the conversation becomes more intimate. For the sake of obtaining some insight into the statistical significance of these results we use a Kruskal-Wallis non-parametric one-way analysis of variance, to test the hypothesis that the medians of all the events are equal. Of course this hypothesis is rejected with P=0 (effectively). Then a multiple comparisons test with simultaneous significance level of 5% shows that the questions fall into clusters as follows:

Events 7, 20, 21, 22, 23 have median significantly greater than all of the others;

Events 6, 8, 9, 10, 11, 18, 19 have medians significantly greater than the remainder.

Event 17 has median significantly greater than the remainder

Events 5, 12, 13, 14, 15 have median significantly greater than 1-4.

Event 15 is not significantly different from 4, 5 and 16

Event 2 (end of baseline) is significantly lower than 3-22.

Note again that event 22 (when the avatar asked the most intimate question) stands out as having the highest median score.

It should be noted that the KW test requires independent observations for each factor being compared, which is not the case here, since the data for each variable is a segment of a time series, so that this analysis should be taken only in a descriptive sense. From the box plots in Figure 4.4 it is clear that events 20-23 together with events 6-10 have greater SCL values than the remainder.

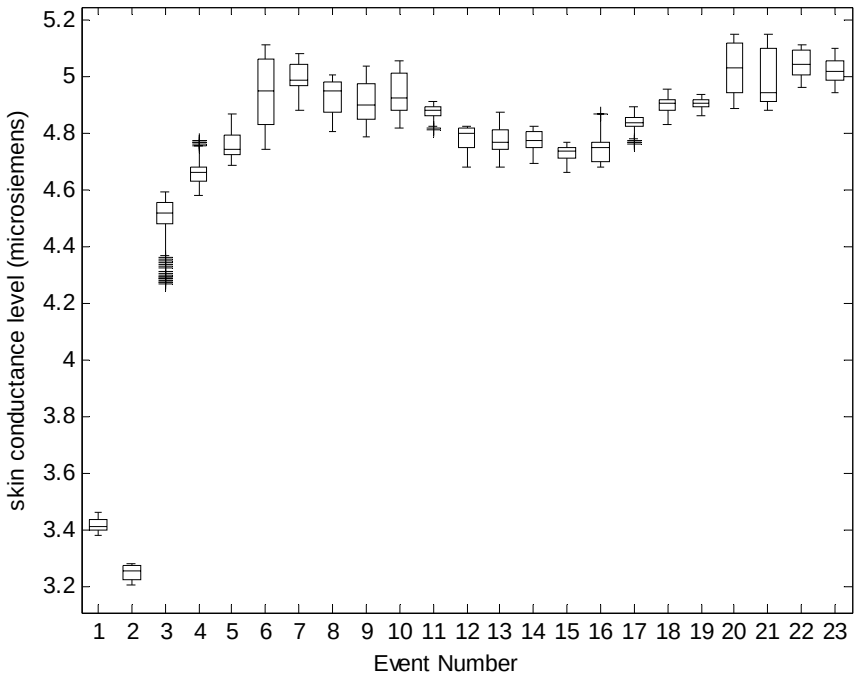


Figure 4.4: Box plots of mean SCL for 10s after an event for each event. These are standard box plots, showing the median and range of values for each event for 10s after the event except for event 2 which is the 10s leading up to the end of the baseline recording.

4.5.3. Bodily Movement Analysis

4.5.3.1 Bodily Movement Annotations

During the experiment the participants were video recorded from the back of the Cave. As shown in Figure 4.5, the video data is with limited lighting condition and with restricted viewpoint. Therefore instead of using a standard annotation scheme (for instance, (Kipp, Neff et al. 2007)) we have formed our own bodily movement annotations. In the context of our experiment, here we considered conversational behaviours which are related with anxiety, domination, flirtation, affiliation, and avoidance. We decompose the bodily movement annotations into 3 categories: hand movement, head movement, and posture movement.

Head Movement: We include nodding, head cocking, head shaking, looking around, and looking down in the head movement analysis. Increased nodding and head cocking (see Figure 4.5 (b)) shows affiliation and higher involvement, whilst look around (Figure 4.5 (d)) and look down (Figure 4.5 (e)) indicates lower involvement (Argyle 1975).

Hand Movement: We consider several general gestures including: hands on hips, head-touch, hands in pockets, hands behind back, hands in front, hands making conversational gesture, and arm crossing. Over these hand movement, we are particular interested in hands on hips (see Figure 4.5 (f), (g), (h), and (i)), which is a dominate behaviour used by male while courting (Argyle 1975). Also we consider head-touching (Figure 4.5 (k)), which is related to self-consciousness within uncomfortable social situations (Knapp and Hall 1978). Certain types of head-touching can also be interpreted as preening which is associated with courting; however, such behaviour is more common in women than men (Argyle 1975).

Posture Movement: We look at posture shifting (symmetric to asymmetric, asymmetric to symmetric, or asymmetric to asymmetric), shrugging, wiggling/swaying, and shifting weights. Similarly to head-touching, shifting weight reflects self-consciousness related to uncomfortable social situation (Knapp and Hall 1978).

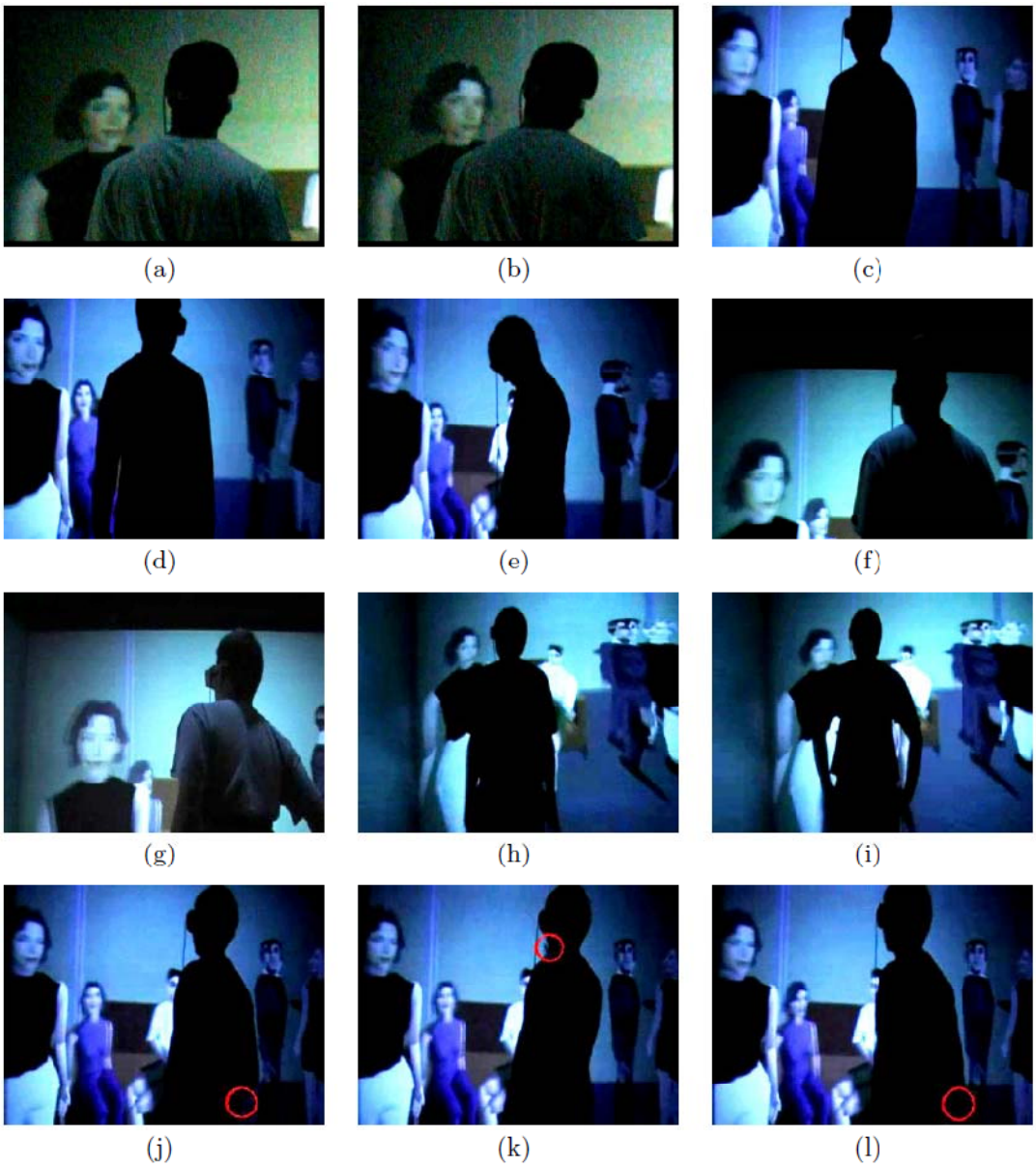


Figure 4.5: Bodily movement annotations: (a) and (b) are the same participant where in (a) his head is straight and in (b) he is doing head-cocking; (c), (d) and (e) shows a participant with normal head position, looking around, and looking down. (f) and (h) show two participants' original positions, (g) and (i) show the same two participants with their hands on hips. (j) to (l) shows the sequence of a participant doing head-touching. His right hand doing the head-touch is highlighted with a red circle.

4.5.3.2 Assessing Body Movements

Two assessment forms were given to a body movement expert who otherwise had no involvement with this research and had no knowledge of its purpose. Form 1 consists of 3 questions each associated with particular events: first, events 16 and 17 where the virtual female asks about the participant's clothes; second, event 18

where the virtual female asks if the participant knows anyone there; third, some participants asked the virtual female to repeat what she has said. In real life these events would trigger the following reactions respectively: first, look down at their clothes; second, look around at other people in the social environment; third, lean forward in order to hear the question more clearly. Therefore the 3 questions we asked on Form 1 were:

- When the virtual lady mentioned the participant's clothes (shirts and trousers), did he *look down* at his shirts/trousers?
- How many times the participant ask the virtual lady to repeat; and when asking, how many times of these he *leaned forward* to the virtual lady?
- When the virtual lady asked if the participant knew anyone here, did he *look around* at the other Virtual Characters?

The answers to those questions would provide us with evidence of participants having or not responded towards the Virtual Characters as if they were real. On the first form a matrix is given, defined by events as rows and the columns as different body annotations. Each element of this matrix is the number of occurrences of a particular behaviour annotation at a given period. The body movement expert then filled in the assessment forms for each participant by screening the video data from the experiment; 10 hours were needed to conclude this task. The expert was paid for this work.

4.5.3.3 Results

(a) Results of Form 1: Event triggered body movement

The result of event triggered body movement is presented in Table 4.5, where for *looked down* and *looked around* we present the number of participants who did these movements at the time over the total number of participants; for *leaned forward*, we present the number of times the participants have learned forward (when asking the Virtual Character to repeat) against the number of times they asked her to repeat. It can be seen that the majority of participants leaned forward when asking the avatar to repeat a question, and looked around when being asked about other “people”. Note that the leaning forward made no sense from an objective point of view since the sound was not localized and therefore was not

actually coming from the perceived location of the virtual woman. These results suggest that the participants' bodily responses towards the female were similar to how they would respond to a real person.

Table 4.5: Event triggered body movement: 1. The number of participants who looked down when asked about their clothes / all participants observed. 2. The number of participants who looked around when asked about other "people" / all participants observed; 3. The times participants leaned forward when asking the virtual lady to repeat / times asked the virtual lady to repeat.

	1, Looked Down	2, Looked Around	3, Leaned Forward
Shy Participants	6/12	11/12	9/9
Confident Participants	7/12	10/12	13/15

Event triggered results show that the participants tended to respond towards the virtual female as if she were real. It is also very interesting to point out that, in spite of the obvious fact that they were in a Virtual Reality, when participants were asked by the Virtual Character whether they knew "anybody" in the party, almost all participants looked around to "check" before answering this question. Again, this makes no rational sense, unless it is considered that the participants were automatically behaving as if this virtual scene were real.

(b) Results of Form 2: Variation of Response with Independent Variables

Consider any particular action such as 'head touching'. We are interested in whether there are any systematic variations of this response with the independent and explanatory variables of the experiment. The null hypothesis is that 'head touching' occurs at random through time. Under this null hypothesis the distribution the number of head-touches should for each individual follow a Poission distribution. Therefore we use the Poisson log-linear model as the appropriate model for analysis of variance of the response variable on the independent and explanatory variables.

In Table 4.6 we show the results of a series of such log-linear regressions. In each case the Poisson model fits well within the bounds of the traditional 5% significance level, and we show the significant explanatory variables, whether their association with the response is positive or negative, and the corresponding significance level.

Table 4.6: Variations of Response with Independent and Explanatory Variables

Categorise	Response Variable	Independent Variables	Association	Significance Level
Head Movement	Look around	Observed	+	0.00
	Look down	Shy	-	0.01
	Nodding	Observed	-	0.06
Hand Movement	Head-touch	Observed	-	0.00
Posture	Shifting weights	Observed	-	0.00

These results show that:

- For head movement, participants who were observed by other Virtual Characters tended to look around more and nod less than participants who were not observed, shy participants tended to look down less than confident participants.
- For hand movement, observed participants tended to head-touch less.
- For posture, observed participants tended to shift weights less than participants who were not observed.

The results suggest that between the shy and confident conditions, there is only one significant result related to this factor. This suggests that with the annotation we have chosen, it is difficult to distinguish shy and confident participants by their behaviour. The only significant result shows that confident participants tended to look down more during the conversation. This might indicate that confident participants had lower involvement with the interaction and paid less attention to the virtual woman (Argyle 1975).

The results show participants who were observed by other Virtual Characters looked around more, and nodded, head-touched, and shifted weights less. The fact that they look around more when being observed fits our expectation because it coincides with human being's normal social behaviour of looking around when being observed by others. Less nodding, head-touching, and shifting weights furthermore suggest that participants who were observed may have been distracted and therefore paid less attention to the virtual female.

4.5.4 Comments and interviews

Immediately after the experiment the participants were interviewed about their responses. This is always useful to shed more light on what has happened that is possible through fixed questionnaires, behavioural or physiological data. We report here a selection of unedited comments that gives some insight into the responses of the participants. The first three responses highlight the strong realism in the responses of the participants:

"The background music, whether dimmed deliberately or not, sounded like the sort of music you would experience at the party, and so added to the realism. Something that has disturbed me about the experience was the physical and emotional changes I felt when speaking to the 'woman'. As she got closer to me and more suggestive in her comments, I found myself responding in a sexual manner, I'm hoping that this doesn't make me a freak!"

"I was amazed most of all when the virtual woman started coming on to me - I felt guilty as I am involved with someone and felt tempted to do something illicit. The idea of cheating on my partner with this virtual woman caused a real physical and emotional response - this was the strongest and most surprising aspect of the experience."

"The initiation of a conversation by the woman and the sheer life-like quality of the conversation at most times made me unaware that I was surrounded by others in a party. This was particularly the case as she moved much closer to talk to me. I am impressed and a little surprised at just how close to real life this Virtual Reality study is!"

The final quote also shows how, in Virtual Reality, things can go wrong:

"The feeling of immersion was considerably lessened when the woman I was talking to appeared to lose an arm. I was surprised by how much the experience benefited from being able to see depth in the people moving around. This particularly noticeable when things catch your attention in your peripheral vision."

4.6 Conclusion and Problems

Some interesting hypotheses were generated that formed the basis of our subsequent study. First, socially anxious males have levels of reported anxiety

(questionnaire based) in response to a virtual woman correlated with their reported levels of anxiety in real life. Secondly, from their behavioural responses, participants who were observed by other "people" were less involved in the interaction with the woman. However, contrary to the expectation that shy males would be made more anxious by other (virtual) characters watching them, this did not show up in the results. Third, there was a clear arousal effect produced by the intimate statements and questions by the woman, as evidenced by the SCL analysis. In other words people responded appropriately in comparison with how they would be expected to behave in a similar real-life situation.

Due to equipment failure we obtained only complete data for the subjective results (questionnaire), and incomplete data for the physiological results. Therefore we treat the above experiments as a pilot study. We have carried out more studies with the same scenario which we present in the following Section.

4.7 Results of the Updated Experiment

Although with the results presented in the previous Section we have gained insight into the behaviours of shy and confident participants relatively to avatars in a Virtual Environment, without sufficient physiological results, it is difficult to justify those findings. Therefore we performed the same experiment with another 36 participants. In this Section we present the results from the updated experiment, starting with a brief summary of new materials used, the recruitment process, and experimental procedures.

4.7.1 Materials

The experiment was conducted in the CAVE-like system as described in Section 4.3.1. The only change was the replacement of the ProComp Infiniti physiological recording device with a Nexus 10. The participants were fitted with the Nexus 10 to record the ECG (1024Hz) and EDA (128Hz). Electrodes were placed on the palmar areas of the index and ring fingers of the non-dominant hand in order to record electro-dermal activity. Electrodes were placed on the left and right collar bones and the lowest left rib in order to record ECG.

4.7.2 Recruitment and Procedures

Participants were again recruited by posters and email on the campus at UCL to all levels of staff and students, with finally 8 to 11 participants in each of the 4 cells of the factorial design (in all 36 participants), as shown in Table 4.7.

Table 4.7: Number of participants for each condition

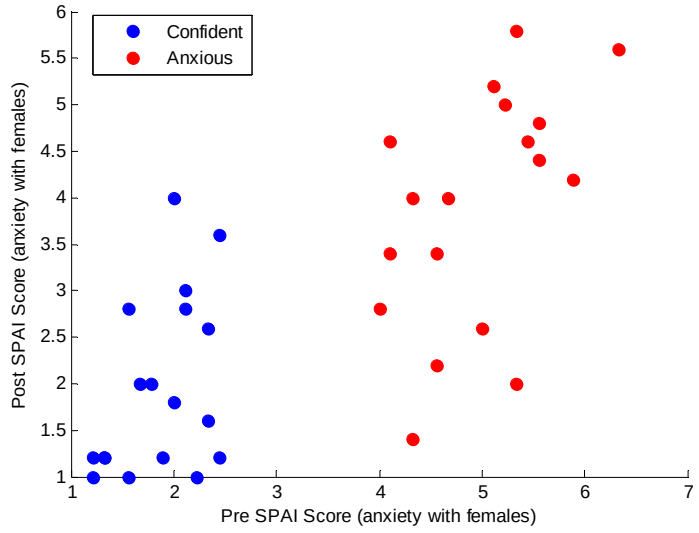
	Not Observed	**Observed**
Confident	9	9
Anxious	10	8

The pre-SPAI questionnaire was put online and advertised the link through emails and posters on the campus at UCL. 136 people filled in the online pre-questionnaire, and the highest scoring 30% and the lowest scoring 30% were invited, and eventually 36 participants were recruited and attended our studies. The mean age was 26 (from 18 to 35) years with no significant difference in age within the 4 conditions: 6 of them were undergraduates, 14 Master students and 9 PhD students. The rest were 1 university staff, 1 architect, and 1 IT worker. The other 4 didn't specify their occupation. They were all fluent in English.

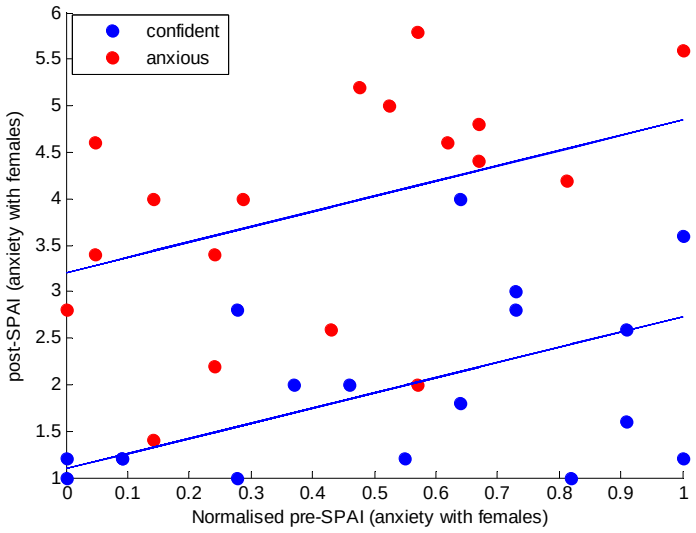
The procedures remained the same as described in Section 4.4.2. The experiment was conducted by the same experimental operator (female) with a male assistant.

4.7.3 Questionnaire Results

The post-SPAI questionnaire, which was administered to participants immediately after leaving the Virtual Environment, tested participants' anxiety during the experience in the CAVE in general as well as their anxiety towards the virtual female. Here we use the score which was related to their anxiety on encountering the virtual female. In our analysis, we compare participants' anxiety level towards female in their real life, which was measured by the pre-SPAI questionnaire. We define the results of the pre-SPAI questionnaire restricted to the questions about relationships with females the *pre-Exposure* scores and the results from the questionnaire administered immediately after their virtual encounter the *post-Exposure* scores.



(a)



(b)

Figure 4.6: Scatter plot of the post-exposure SPAI scores against the pre-exposure scores classified by anxiety group. (a) The raw scores and the correlation between the pre- and post-exposure scores is 0.43 (P = 0.08) for the confident group and 0.51 (P = 0.03) for the Anxious group. (b) The pre-experience scores are normalized separately for each group. Analysis of covariance of the post-experience score by group using the pre-experience score as the covariate shows that there are two parallel lines, with the intercept of the Anxious group greater than that of the Confident group (P < 0.0001).

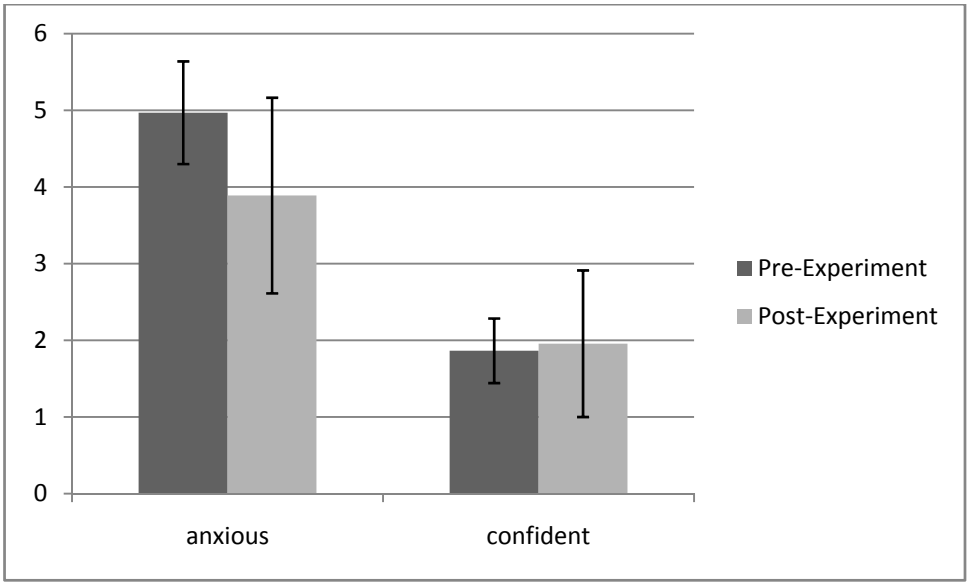


Figure 4.7: The average and standard deviation of the Anxious and Confident groups for the pre- and post-Experience questionnaire scores. A paired sign test shows no significant difference between the pre- and post-experience scores for the confident group (P = 0.81) but a significant difference for the Anxious group (P = 0.0075).

Figure 4.6 and 4.7 shows the pre- and post-exposure questionnaire scores. From Figure 4.6 (a) by the experimental design the pre-exposure scores are well separated between the Confident and the Anxious group, and within both there is a positive association between the two scores (significant for the Anxious group). Standardizing both sets of pre- exposure scores to have mean 0 and standard deviation 1 so that we can clearly compare post- exposure scores between the groups we can see (Figure 4.6 (b)) that the Anxious group generally reports greater anxiety with respect to the encounter with the virtual woman compared to the Confident group. However, if we examine the change in scores separately for the Confident and Anxious groups we find that there is a significant reduction in anxiety amongst the Anxious group (Figure 4.7).

4.7.4 Physiological Data Analysis

With our previous SCL data we have found that participants were anxious at the beginning of the interaction as well as towards the end when the interaction was more intimate, and they were more relaxed in between. In order to further investigate our pervious finding we take a difference approach for data analysis: we have divided the interaction with the virtual lady into 3 different segmentations with

different intimacy levels. Therefore, together with the baseline, there were four distinct phases to the whole experience: *baseline* – where the participant was in the bar alone, music was playing but nothing else happened; *start* – where the virtual woman approached the participant and initiated a conversation; *mundane* – where the conversation was mainly about everyday matters such as places for living and work; *intimate* – where the character moved to intimate distance, personal matters were discussed, complements given, and the issue of another meeting raised. The detailed segmentation is shown in Table 4.8.

Table 4.8: Events segmented into 4 different periods as the intimacy level increases.

Baseline	
1	Baseline starts
2	Baseline ends
Start: The virtual Female initiates the conversation	
3	Experiment starts
4	Avatar stares at the participant
5	Avatar approaches to within normal social distance
6	“Hi, It looks like we are the only people alone here, right?”
7	“My name is Christina.”
8	“It's very nice to meet you.”
9	“So, what are you doing for a living?”
10	“Very interesting, tell me more.”
11	“I'm an air hostess; I just arrived in London yesterday. Where do you live?”
Mundane: “Everyday life” conversation	
12	“I don't know London very well, but actually, I am thinking about moving here, what do you think?”
13	“But I heard it rains all the time here, is that true?”
14	“Well, the weather is not that important to me. Have you lived here long?”
15	“Do you like it here?”
16	“I've noticed that people dressed very well around here. By the way, that shirt looks great on you. How much was it?”
17	“Ah, I really want to find a pair of trousers, something like these (Looking down) for my brother. Where did you get these?”
Intimate: The conversation became more intimate	
18	“So, do you know anyone here?”
19	“I feel a bit shy about talking with other people, do you mind if I talk with you for a bit longer?”
20	The avatar approaches to an intimate distance
21	“If you don't mind me saying, I think you look very nice.”
22	“I was wondering actually, are you single, or involved with someone at this time?”
23	“Maybe we should meet up.”

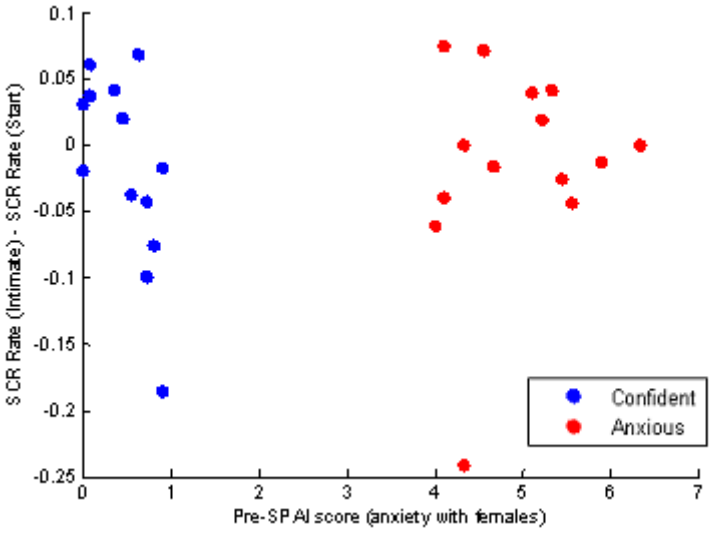
(a) SCR analysis

Skin conductance responses (SCR) were defined to be local maxima that had amplitude of at least 0.1 μS and in a period not exceeding 5s from the start of the SCR to its maximal point (Slater, Guger et al. 2006). The amplitude refers to the maximum level reached compared to the start of the SCR. Of interest are both the number and amplitude of SCRs, and we also refer to the SCR rate as the number of SCRs per second. Such SCRs were identified in an offline program written in MATLAB.

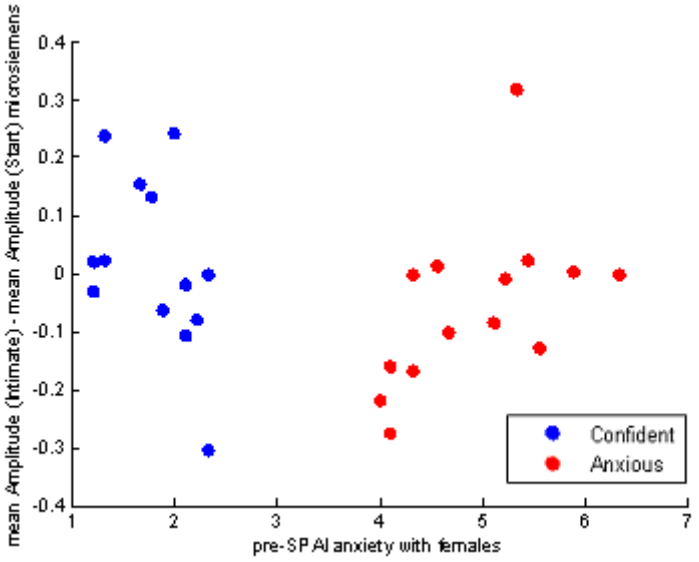
Among all 36 physiological recordings 9 were eliminated for Skin Conductance analysis due to bad data. This may have been caused by the participants' finger being too dry or due to large amplitude movement which may have caused a bad cable connection, thus interrupting the recording. Therefore in the skin conductance analysis we used 27 physiological recordings. Here we consider the rate and amplitude of SCR that followed the events as defined in Table 4.8. We expected greater arousal for the Anxious group in the *intimate period* compared to the *mundane* or *start period*. During each of the periods Start, Mundane and Intimate the same type of events were occurring – the virtual woman asked questions or made statements to which the participant answered. Therefore the most useful comparisons will be between these time periods. In particular, we are interested in whether there are differences between the *intimate period* and those before this.

Figure 4.8 shows plots of the change in skin conductance between the start and intimate period by the pre-Experience scores both for the rate of SCRs per second and the mean amplitude. In the case of Figure 4.8 (a) there is no significant correlation. In the case of (b) for the Anxious group there is correlation between the pre-Experience score and the difference in amplitude is positive with $r = 0.52$ and $P = 0.051$.

Figure 4.9 shows the change in heart rate between the start and intimate periods. It is clear that both for the Confident and Anxious groups that the heart rate increased between the intimate and start period.



(a)



(b)

Figure 4.8: Difference in SCR between the intimate and start periods by pre-Experience SPAI scores. (a) Shows the SCR rate and (b) the mean amplitude of the SCRs.

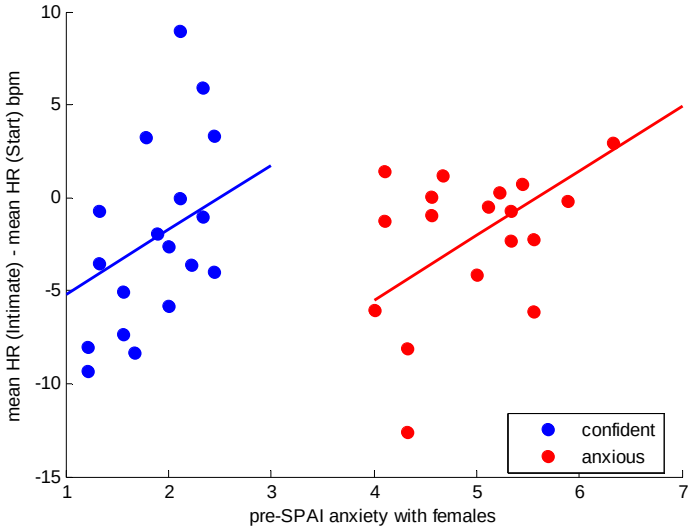
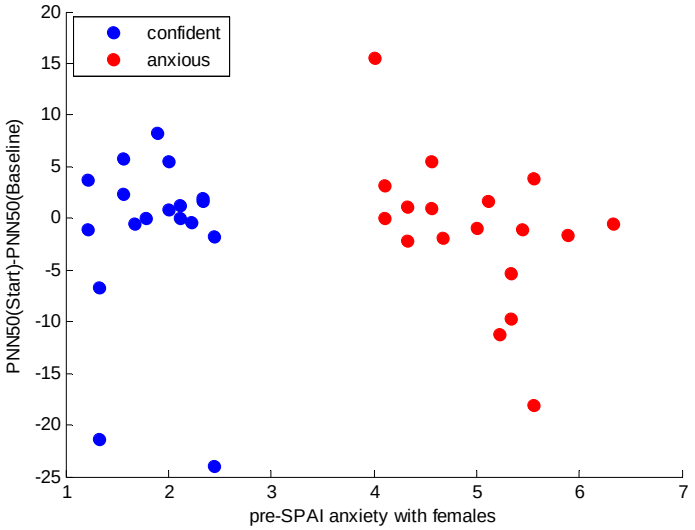


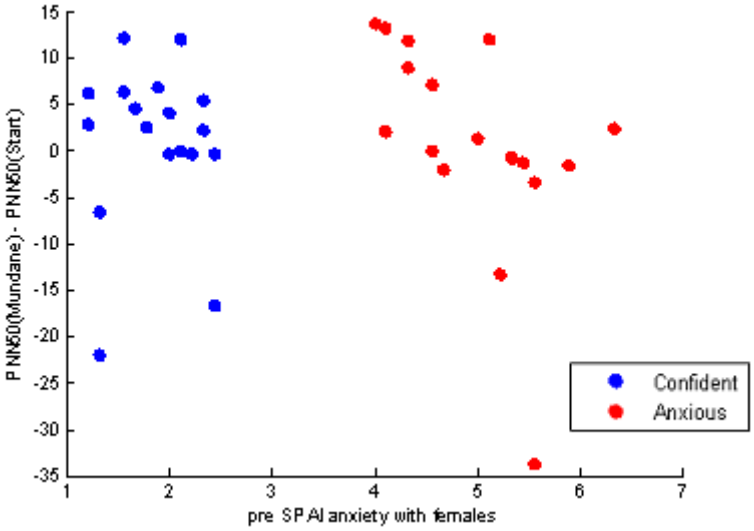
Figure 4.9: Difference of mean HR between the Intimate and Start periods. Analysis of Covariance finds two parallel lines that are significantly different (P = 0.0097).

(b) ECG analysis

Of greater interest is the heart rate variability that we measure using the PNN50 criterion (Percentage of differences between adjacent NN intervals that are >50 ms) (Task-Force 1996). Figure 4.10 shows that decreases in PNN50 between the *start* and baseline period, and between the baseline and *mundane* period are greater the greater the anxiety level amongst the Anxious group. Figure 4.10 (a) gives a comparison between the confident and anxious group for difference in PNN50 for the Start minus the Baseline period. There is no significant effect for the Confident group, but a regression analysis shows that for the Anxious group there is a significant negative correlation (P = 0.0491, R^2 = 0.22). A similar situation occurs when comparing the Baseline with the Mundane period (Figure 4.10 (b)) (P = 0.03, R^2 = 0.26). However, when we compare the Intimate period with the Baseline the significant effect for the anxious group has diminished (P = 0.11). Although most of the graphs plotting differences of PNN50 against the SPAI score show negative trends for the anxious group, no others are significant. This suggests the anxiety level decreased for the Anxious group in the intimate period.



(a)



(b)

Figure 4.10: PNN50 by pre-Experience SPAI score (a) comparing Start to Baseline and (b) Comparing the Mundane period to the start.

4.7.5 Body Movement Analysis

An assessment form was given to a body movement expert who otherwise has no involvement with this research and had no knowledge of the purpose of our research.

Here we are interested in, during the interaction, if the participants exhibited appropriate bodily response after particular events. Therefore we asked 4 questions on the form:

- When the virtual lady was approaching the participant to a close distance, did he step backwards?
- When the virtual lady mentioned the participant's clothes (shirts and trousers), did he look down at his shirts/trousers?
- When the virtual lady asked if the participant knew anyone here, did he look around at the other Virtual Characters?
- How many times the participant ask the virtual lady to repeat; and when asking, how many times of these he leaned forward to the virtual lady?

The answers to those questions would provide us with evidence if the participants have responded towards the Virtual Characters as if they were real.

Table 4.9: Bodily movement analysis of the shy and confident participants. The number of participants who 1. stepped backwards when the virtual female approaches the participants to an intimate distance; 2. looked down when asked about their clothes; 3. looked around when mentioned "other people"4. leaned forward when asking the avatar to repeat / All participants observed.. Also in 4. the number of times the participants has learned forward (when asking the Virtual Character to repeat) against the number of times they asked her to repeat.
(* significant at < 0.001.)

		Shy Participants	Confident Participants
1	Stepped Backwards*	4/18	0/18
2	Looked Down*	7/18	12/18
3	Looked around	14/18	14/18
4	Leaned Forward	8/11 participants (17/25 times)	11/13 participants (20/26 times)

The result of event triggered body movement is presented in Table 4.9. For each annotation we present the number of shy and confident participants who did the movement at the time over all participant observed; for learned forward, we also present the number of times the participants has learned forward (when asking the Virtual Character to repeat) against the number of times they asked her to repeat. It can be seen that the majority of participants leaned forward when asking the avatar to repeat a question, and looked around when being asked about other "people". Note that the leaning forward made no sense from an objective point of view since the sound was not localised and therefore was not actually coming from the location of the virtual woman. These results suggest that, similar to our previous findings, the

participants' bodily responses towards the female were similar to how they would respond to a real person.

4.8 Comments and Interview

After the experiment the participants were told to fill in two questionnaires, and at the end of the questionnaire they were asked to leave some comments with the following instruction:

- Aspects of the experience that made you respond as if it were real.
- Aspects of the experience that led you to make responses that would have been unrealistic if the situation depicted had been occurring in reality.
- Aspects of the situation that suddenly disturbed your experience of being in the party. Aspects of the experience that helped or hindered you achieving your task.
- Aspects of your feelings towards the experience

After the experiment, we have conducted an interview with the participants. The outline of the interview was as following:

- Did you enjoy the experience?
- How much was your behaviour was like in a real party?
- How does it compare to your normal responses in a real party? Did you feel more anxious or more relaxed?
- Did you have any emotional responses towards this virtual woman?
- There was a point she was really close to you. How did you feel?
- Did you notice other virtual characters at the background?
- Can you describe her personality?

The experimenter follows the outline but was not restricted with the questions listed above. Unfortunately half of the interview tapes were lost in an accident (stolen from the transcriptionist) and only 19 interviews were available (8 shy, 11 confident participants). Here we present a summary of our interview data.

(1). Did you enjoy the experience?

Most of the participants have enjoyed the experience: “That was very, very good”, “I loved it!” But 1 among 19 participants said he did not like it because: “there is nothing to do but make conversation. It’s strange not being able to sit or walking around.” (Confident participant). Another participant said he enjoyed the experience but the woman made him “uncomfortable”, because “She asked too many questions. Just wants to know everything from me.” (Shy participant).

(2) How much was your behaviour was like in a real party?

The experimenter also asked the participants to compare their behaviours to how they would behave in a real party. Most of the participants felt it was very similar, but some didn’t find it was as real: a confident participant said it felt more like a networking session rather than a party; a shy participant said there were senses missing including smell and alcohol.

(3). How does it compare to your normal responses in a real party? Did you feel more anxious or more relaxed?

When participants were asked to compare their anxiety level to their real life experiment, some of them said they were more relaxed in the CAVE because it was unreal, so that they “didn’t feel people would get an impression of me”. One shy participant thought it was pleasant and relaxing because he had a companion who made it easy for him to stay in the party, and also he didn’t need to initiate the conversation. Another shy participant mentioned he was less reserved in the CAVE, for instance in real life he would stand in the corner in a party rather than the middle of the room as he was in the CAVE.

Other participants thought the experience was more stressful than a real life situation. They felt the situation was confined, and the virtual people’s responses were less predictable. In particular, one confident participant mentioned that he would be more relaxed in real life because he would have more feedback (body, gesture) from other people to reassure that he was doing the correct thing.

(4) Did you have any emotional responses towards this virtual woman?

Some participants pointed it out that although the graphics were not very realistic, it didn't stop them from having emotional responses towards the virtual woman. Some thought the questions she asked triggered realistic emotional responses, and some felt strongly her existence: "I felt she was physical. It's natural. She stands in front of me, she walks towards me. It made me act as if I was like in more lifelike experience." One participant was surprised when the virtual woman asked for a date, and thought "it (the surprise) was a normal reaction. That feels real". A shy participant felt very nervous and embarrassed with the virtual woman and lied to her when she asked if he has a girl friend (he said he was involved with someone, but he was actually single). He said he would do the same in everyday life when he felt nervous. Another confident participant said he was surprised at his own emotional response when he had to refuse the woman for a date. He explained because he was married and she obviously wanted to go out with him, he felt very sorry for her and "that (feeling sorry) was full of emotion".

(5) There was a point she was really close to you. How did you feel?

In particular when asked about their feelings when the avatar was getting physically closer and closer to them, many participants said they had physical responses. Some confident participants said: "I was worried that she was trying to kiss me", "I didn't feel like I've moved, but I felt the urge of getting backwards", "when her face was coming straight at me it was sort of, I wouldn't know how to define but some kind of arousal, not physical, just pleasurable". Other participants (both shy and confident) said they felt uncomfortable, sweaty, blushing on the face, and felt their heart rate to be increasing.

(6) Did you notice other virtual characters at the background?

When asked their opinion on the other 4 virtual characters in background, participants who were not observed all said they didn't notice them at all. Other participants said they felt in the beginning that the other virtual characters were looking at them, but as soon as they started the conversation they immediately forgot about them. However, two shy participants were more aware of them. One said: "*I don't know if it was really happening, but when she was asking certain*

questions, which I thought were important questions, then everyone stopped and looked at you as well. I don't know, I could have just made it up", and he thought it was like drawing a spot-light on him, which amplified the emotion and anxiety he had. Another one said, the fact that other characters were looking at him "*was the first thing I'm kind of aware of*", however compared to real life experience, he felt it to be more "interesting" rather than disturbing.

(7) Can you describe her personality?

When asked to give a description of the virtual female's personality, 11 out of 19 participants mentioned at least one of the words "forward", "straightforward", or "confident". Other words used to descript her include direct, outgoing, socially curious, friendly, forthcoming, pushing, bored, lonely, and desperate.

4.9 Summary

From our updated experiment, the questionnaire results suggest that participants had levels of reported anxiety (questionnaire based) in response to a virtual woman correlated with their reported levels of anxiety in real life. However, socially anxious participants felt less anxious interacting with the virtual woman, in comparison with their real life experience.

In the analysis of physiological data we segmented the interaction into three different periods. Both EDA and ECG data further supports that for shy participants, their everyday anxiety level is positively associated with their anxiety during the interaction with the virtual lady. However, the ECG data suggested that a decrease in the association towards the end of the interaction when it became more intimate.

The behavioural data also suggested that participants were responding towards the virtual female as if it were real. The shy participants shown more anxiety than the confident ones as when the avatar approached them to an intimate distance, the shy participants had a stronger reaction.

Our results show that the participants tended to respond to the situation at the subjective, behavioural, and physiological level as if it were real. One of the major problems for males who are shy in relation to women is that they do not have experience of interacting with them. Therefore initial heightened anxiety would be

expected. However, as time progresses there should be an adaptation effect, as suggested by our ECG analysis. This last result is an excellent pointer for the potential utility of this simulation in training and therapy.

In this Chapter, we studied the difference between shy and confident participants' reaction towards a forward avatar. In the rest of the thesis, we will focus on the representation of shyness on Virtual Characters and most importantly participants' responses towards them. In the next Chapter, we investigate how participants respond towards an avatar who blushes.

Chapter 5 Experiment: Blushing

In the previous Chapter we have described a study concerning how shy or confident participants react towards a forward virtual woman. In this Chapter, we further investigate how shyness effects the interaction between human participants and Virtual Characters. Here we look at how male participants react towards a shy virtual woman who blushes. The purpose is to assess the role of blushing in human-avatar interaction. This Chapter is written based on our published paper (Pan, Gillies et al. 2008).

5.1. Motivations

As one of the "most peculiar and the most human of all expressions" (Darwin 1999), blushing is a popular topic in psychological research. It has been proved to be a significant facial cue which serves important functions in interpersonal communication (Leary and Meadows 1991).

The reason why people blush is still debated among psychologists. Most people consider blushing in public an undesirable response and some people even feel embarrassed when they think that people are noticing that they are blushing. Moreover, profound blushing is one of the symptoms that exacerbates anxiety amongst people who suffer from social phobia (Schneier and Welkowitz 1996).

In spite of its importance, little work on blushing has been done in character animation. Moreover, research on how people react towards a blushing avatar has not been reported to date. This neglected area of research is potentially very important because applications in computer character animation, ranging from industrial training to entertainment and psychotherapy, are eventually to be experienced and evaluated by human participants.

In this Chapter we describe an experiment in which there is an interaction between a person and an avatar, the goal of which is to assess the role of blushing on the person's responses. We view this as an initial experiment in this domain, where a methodology is introduced for studying the impact of blushing using a behavioural response measure. The overall goal is to initiate research to find whether blushing on Virtual Characters might improve the quality of interaction between people and Virtual Characters. In previous research we have studied male

human participants' reaction towards a forward female avatar (Pan and Slater 2007). In this Chapter we evaluate the empathic interaction between male human participants and a virtual woman who exhibits signs of embarrassment through blushing.

5.2. Hypothesis

From our literature review (Section 2.5 Social Blushing) we have learnt that blushing has a remedial effect in interpersonal communication. Our goal in this experiment was to test the hypothesis that when male participants are interacting with a blushing female avatar, although they may not consciously notice the blushing on the Virtual Character, will nevertheless feel more sympathy towards her, and be more tolerant to her mistakes.

5.3. Experimental Design

Compared to inducing blushing in an experimentally controlled way on real people, rendering the appearance of blushing on avatars with current computer animation technology is not difficult, especially if there is no attempt at photo-realism, but rather at giving the impression of blushing. However with the intention of provoking and evaluating people's natural responses towards blushing, the experimental design is critical. In this Section we first define our research questions, followed by a description of the factorial experimental design, and finally we present the design of the scenario and the materials.

5.3.1 Research Questions

Questions associated with our main hypothesis were:

- Would participants consciously notice blushing on an avatar?
- Psychological studies have shown that blushing has a remedial effect, with paper-based scripts. However, would avatar blushing have a similar remedial effect, and provoke higher degree of sympathy in the participants?
- In the context of Virtual Reality, we were particularly interested in whether blushing increases/decreases the degree of co-presence (see Section 2.5) between the avatar and the participant?

5.3.2. Factorial Design

We were interested in how people respond towards a blushing avatar compared to responses towards a non-blushing avatar. Here two main different types of blushing for rendering were considered: “rosy cheek” and whole-face blushing (Patel 1995). Related psychological literature also discusses both blushing effects (Shields, Mallory et al. 1990). In our work, both blushing effects were implemented. As shown in Fig. 5.1, three factors are included regarding blushing: non-blushing (see Figure 5.1(b)), whole-face blushing (Figure 5.1(c)), and rosy-cheek blushing (Figure 5.1 (d)). In all conditions the same female avatar was used and we invited only male participants for our study. This is because, as mentioned in the introduction, in our research we are interested in empathic interaction in the context of shyness between members of the opposite gender.

(a) (b) (c) (d)

Figure 5.1: Factorial Design: Before the “incident” happens, the virtual woman looks cheerful (a). After the incident happens, she apologises to the participants, and looks slightly embarrassed, without blushing (b), with whole-face blushing (c), or with cheek blushing (d).

5.3.3. Scenario

In this work we intended to induce participants’ natural responses towards a blushing/non-blushing avatar, without revealing our purpose during the experiment. In the experiment, participants were told that some information would be presented to them about the 2008 Olympic Games by an avatar who would present a video. However, repeatedly, this video failed to load, the avatar apologised, and the interaction started over again. There were three conditions in a between-groups experiment, with 11 participants per group. In one condition the avatar never blushed, and in the two other conditions either whole face or partial face blushing became increasingly apparent on the avatar’s face as the program seemingly failed to load. After each failure the participant could either end the interaction or try again. Our major question of interest was whether participants would be influenced by the blushing, and whether they would tolerate a greater number of trials than in

the situation where there was no blushing. The scenario of the experiment is described as following:

(1) A cheerful avatar (see Figure 5.1(a)) gives a presentation on a chosen topic to the participants.

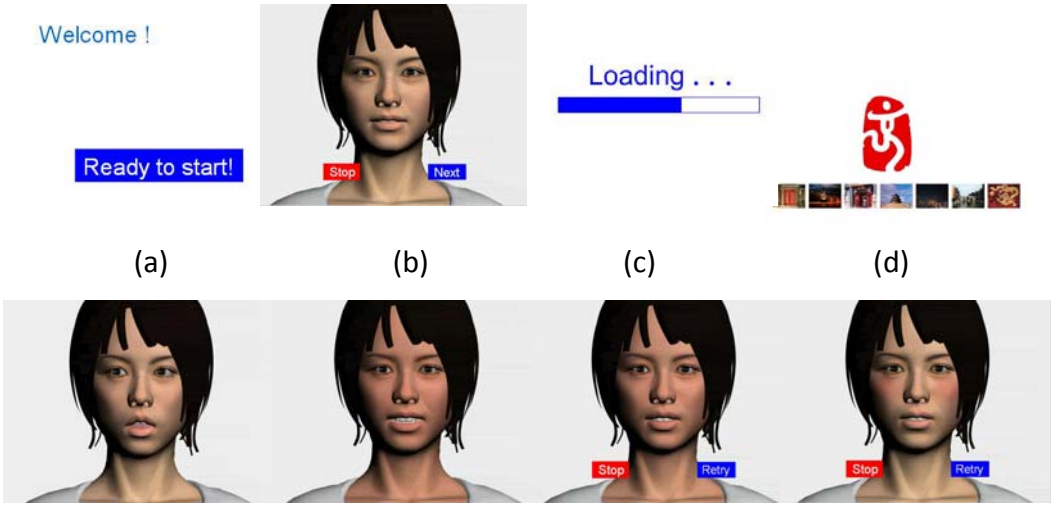
(2) During the presentation, an "incident" (simulated database loading problem) happens.

(3) The avatar then apologises to the participant asking him to wait. When doing so, the avatar looks slightly embarrassed, with or without blushing (Figure 1(b), (c), and (d)).

(4) The participant then has to choose either to stop the experiment or to continue.

(5) Repeat (3) and (4), until the participant chooses to stop; or the experimental trial is terminated after 10 repetitions.

5.3.4. Materials



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 5.2: The procedure of the experiment. The participants had to click to start (a), and choose to continue or stop by clicking "stop" or "next" (b). After showing a loading bar (c), the virtual agent introduced the emblems and the mascot of the 2008 Olympic Games with animated graphics (d). After that, there appeared to be a failure in the computer program to load the next sequence, by showing the animated loading bar twice (c). The virtual agent then appeared to be surprised (e), and feeling sorry with a blush on her face (f). The participant had to choose either to "retry" or to "stop" (g), (h).

The animation of the avatar was developed with 3DsMax[10]. Her facial expression was implemented to be either cheerful (see Figure 5.1(a)) or slightly embarrassed (Figure 5.2(f)), with blinking and head movements. The avatar's lip movements were synchronized to the audio with Voice-O-Matic[11]. The user-interface and other animations were developed with Adobe Flash[12], where the participants could use the mouse button to start (Figure 5.2(a)), and choose to continue or to stop (Figure 5.2(b)) the experiment.

Both whole-face and cheek blushing effects were rendered by blending two facial texture maps over time (3 seconds, 30 frames per second) in 3DsMax. After reaching the highest intensity (a pre-set blending parameter), the blushing then slowly reduced to a lower intensity until the end of each video clip. The intensity also increases at each video clip.

The experiment was conducted on a desktop machine running Windows XP. The participants were seated about half a meter away from the 17" computer display. They were given a set of headphones to listen to the experiment and the mouse to interact with the user-interface (see Figure 5. 3).

5.4. Measurements

5.4.1. Behavioural Measurement

Our premise was that if the avatar blushes, the participant would wait longer before terminating the experiment due to sympathy evoked by the blushing. Therefore our primary behavioural response variable was the number of times each participant chose to continue, and in particular whether they would continue with all 10 trials. They were not informed in advance about how many trials there would be.

The time the participant spent during the whole experiment was also recorded. Additionally, right after the experiment, the participants were asked to give an estimation of how long they had spent on the experiment.

[10] http://www.autodesk.co.uk/
[11] http://www.di-o-matic.com/
[12] http://www.adobe.com/

5.4.2. Questionnaire measurement

Other measurements were based on data collected with questionnaires. These included:

(a) A pre-questionnaire was used to record basic information about the participant such as age, gender, status, and prior experience of Virtual Reality and computer games.

(b) To investigate the relationship between the participant and the avatar, a standard POMS (profile of mood states) questionnaire was used twice to assess their change of mood states, both before the experiment and after the experiment (McNair, Lorr et al. 1992).

(c) Moreover, as a primary measurement, we evaluate participants' behaviour, which may also be influenced by their personality.

(d) Therefore we have also used the NEO big five factors questionnaire in order to include their personality as an additional factor in our analysis (Costa and McCrae 1992).

(e) Finally, a post questionnaire was used to assess their experience towards the personal trait of the virtual agent and how they feel about the "incident". This questionnaire also included co-presence and blushing related questions. All questions are described as follows:

(1) **Evaluation questions** asked how the participants think about the avatar, considering her *reliability*, *honesty*, *sociability*, *friendliness*, and if she was *sympathetic* and *likable* (for example, 1: unlikable, 7: likable). We also asked the participants to indicate the seriousness of the incident, as well as to what extent they considered the avatar as responsible for the incident (for example, 1: not responsible at all, 7: highly responsible). These questions were taken from de Jong's experiment on blushing (de Jong 1999). Regarding our setup, we asked two additional questions: first, if the participants thought she felt sorry; secondly, if they thought she felt embarrassed.

(2) There were three **co-presence questions** asking the extent to which participants find themselves responding to the avatar as if she were a real person, concerning their *thoughts*, *feelings and emotions*, and *physical responses* (1: not at all; 7: very much).

(3) **Blushing related questions** asked the extent to which the participant (a) *thought that the avatar has blushed* (1: not at all; 7: very much), (b) *generally notices other people blush* (1: not at all; 7: always), (c) *usually blushes* (1: not at all; 7: very much), and (d) *has blushed during the experiment* (1: not at all; 7: very much). These blushing related questions were asked on a separated sheet which the participants were to answer in the end after the whole experiment. There was no other mention of blushing during the whole experiment, and they only see these blushing related questions at the very end of the experiment.

5.5. Procedures

5.5.1 Recruitment

The experiment was approved by the UCL Research Ethics Committee. Participants were recruited by email on the campus at UCL to all levels of staff and students, with finally 33 male participants (11 for each condition). The mean age was 20 (ranging between 18 and 28) years with no significant difference in age within the 3 conditions. Among the 33 participants, 29 were undergraduates and 4 were master students. They were all native English speakers.

5.5.2 Procedures

The experiments were carried out in January and February, 2008. Participants attended the experiment at pre-arranged times. After arriving, the participants were given an information sheet, a consent form, and the pre-questionnaires. After that they were shown the lab and seated in front of the computer. They were then told that they would watch a presentation about the 2008 Olympic Games and to follow the instructions provided by the virtual agent in the presentation which would last about 5 minutes. They were also informed that their reaction to the quality of the interface would be studied. The experimenter then left the participant alone in the room (Figure. 5.3).

The reasons why we chose the 2008 Olympic Games as the topic of the presentation were, first, it was topical for the majority of participants. Secondly, the Olympics attracted general interest in the public. With these two reasons, the chosen topic was intended to enhance the participants' curiosity during the

presentation and increase the likelihood that they would want to watch the presentation.

The presentation started with a virtual agent representing a Chinese woman introducing information about the 2008 Olympic Games to the participant (See Figure 5.2 (a), (b)). After introducing the emblems and the mascot of the 2008 Olympic Games (Figure 5.2 (d)), there appeared to be a failure of the computer program to load the next sequence properly (Figure 5.2 (d)). The virtual agent then appeared to feel sorry, with slightly embarrassed facial expressions, and apologised to the participant for the inconvenience (Figure 5.2 (e), (f)). She suggested that the participant wait a bit longer but also mentioned that they could give up and leave anytime they wished. Then the participant had to choose either to "retry" or to "stop" the presentation (Figure 5.2 (g), (h)). A similar "error message" would occur 10 times, with the virtual agent saying different apologetic sentences each time.

The whole scenario lasted between 3 and 8 minutes, depending on when the participant chose to stop. The number of times participants chose to "retry" when the "incident" happened was recorded. After completion the participants then were given the post-questionnaires.

Figure 5.3: A participant deciding whether to stop or to continue the presentation.

5.6. Results

5.6.1. Did the participant notice the blushing?

Our first concern is the extent to which the participants noticed that the avatar had blushed. Table 5.1 shows the mean value of the extent to which they have

noticed the avatar was blushing (1: not at all; 7: very much). The results suggest that cheek blushing was more noticeable than the other two, but in fact the only significant difference was between cheek blushing and no blushing.

Table 5.1: Mean value of the extent to which participants noticed that the avatar was blushing. (1: not at all; 7: very much), n=11 for each condition. A one way analysis of variance on the null hypothesis that the means of all three groups are equal has significance level P = 0.053. A multiple comparisons tests at the 5% level on the differences between the means reveals that the mean for condition 3 is significantly greater than the mean of condition 1 (no other comparisons are significant). The Jarque-Bera test does not reject the hypothesis that the residual errors of the model follow a normal distribution.

Condition		Mean	Standard Deviation
1	Non-blushing	2.0	1.09
2	Whole-face blushing	2.7	1.62
3	Cheek blushing	3.7	1.95

5.6.2. Behavioural measurement: Stopping time

We have recorded the times that each participant pressed "continue" before choosing to stop. Among the 33 participants, 18 of them pressed the "stop" button before termination of the experiment. The remaining 15 participants carried out the experiment until finally the program terminated after 10 trials.

Table 5.2 shows the proportions of people who continued to the end under each of the three conditions and it is clear that less people continued to the end under the cheek blushing condition.

Table 5.2: Proportion of participants who continued to the end for each condition. n = 11 for each condition.

Condition		Proportion	Standard Deviation
1	Non-blushing	0.55	0.52
2	Whole-face blushing	0.63	0.50
3	Cheek blushing	0.18	0.40

In order to test the significance of this, and also to relate it to other variables we constructed a binary variable (*continued*), which indicates whether they did stop

voluntarily (0) or carried on throughout the whole experiment but were forced to stop after the 10th trial (1).

We carried out a binomial logistic regression with *continued* as the dependent variable, and condition as the independent variable. In this case condition 3 has a lower proportion than condition 1 and 2 with significance level $P < 0.09$. When we included the NEO questionnaire it was found that "Agreeableness" was significantly and positively associated with continued – in other words a positive association between the degree of "Agreeableness" and continuing with the trials until stopped by the program. Therefore we included "Agreeableness" in the binary regression as shown in Table 5.3. The results suggest that participants were more likely to stop in Condition 3 compared to 1 or 2, and that there was no difference between condition 1 and 2. Moreover, they were more likely to continue, the higher their score on Agreeableness.

Table 5.3: Binomial Logistic Regression of Continue (1 if the participant continued to the end and 0 otherwise) on Condition (type of blushing) and the Agreeableness (NEO questionnaire). Deviance = 35.12, ∂.f. = 29. Condition 1 is subsumed under the constant term, and the coefficients for Conditions 2 and 3 are differences from Condition 1.

Term	Coefficient	P
Constant	-4.1	
Condition 2 (whole-face blushing)	0.52	0.59
Condition 3 (cheek blushing)	-1.97	0.07
Agreeableness	0.14	0.05

5.6.3. Co-presence questionnaire

There was a difference between condition 2 and condition 1 and 3 with regard to our "co-presence" questions. Table 5.4 shows the average value and the standard deviation for the three questions related to co-presence. Condition 2 has a higher mean in all 3 questions. Table 5.5 shows the regression analysis of "co-presence" on condition, the NEO questionnaire, and the blushing condition. The results indicated that there is no association between "co-presence" and Conditions 1 or 3, but that it is positively associated with Condition 2. Regarding the correlation with the

participant's personal trait, it is negatively associated with Openness, and positively associated with the extent to which the participants report that they generally notice others blush.

Table 5.4: Mean and standard deviation of the co-presence questionnaire. n = 11 for each condition.

Co-present		Thoughts	Emotions	Physical
1	Non-blushing	.5±1.7	2.5±1.7	2.5±1.9
2	Whole-face blushing	3.6±1.1	3.5±1.4	3.6±1.8
3	Cheek blushing	2.5±1.4	2.5±1.4	2.2±1.6

Table 5.5: Regression analysis of "Co-presence" (the mean of the three co-presence questions) on condition, and "Openness" (NEO questionnaire), and "other blush" (the extent to which the participants report that they generally notice others blush, from the blushing questionnaire). R^2 = 0.50, ∂.f. = 28. A test of the residuals of the model does not reject the hypothesis of normality (P = 0.46 on a Jarque-Bera test for normality).

Term	Coefficient	P
Constant	4.3	
Condition 2 (whole-face blushing)	1.5	0.00
Condition 3 (cheek blushing)	0.44	0.37
Openness	-0.11	0.01
Others blush	0.33	0.02

5.6.4. Other questionnaires

No statistically significant differences were found in relation to the POMS, the personality trait, and the evaluation of the incident questionnaire. However, as shown in Table 5.6, there is a tendency that, with the whole face blushing avatar, participants rated her as more reliable, and reported that she felt sorrier about the incident. With the cheek blushing avatar, the participants tended to consider the avatar as more responsible for the "incident".

Table 5.6: Mean and standard deviation of the personal trait and evaluation of the incident questions. n = 11 for each condition. 1: What are your feelings about the avatar? Is she: reliable/honest/social/friendly/sympathetic/likeable? 2: How do you assess the seriousness of the incident? 3: How much do you consider her as responsible for the incident? 4: How much do you think she felt sorry about the incident? 5: How embarrassed do you think she was about the incident?

Measures	Conditions		
	Non-blushing	Whole face blushing	Cheek blushing
reliable[1]	3.5±1.5	4.6±1.3	3.7±1.7
honest[1]	4.1±1.5	4.6±1.5	3.9±1.8
social[1]	4.8±1.7	4.5±1.5	4.9±1.3
friendly[1]	5.4±1.4	5.1±1.1	5.1±1.0
sympathetic[1]	4.9±1.5	5.1±1.4	4.6±1.1
likeable[1]	4.5±1.5	4.5±1.5	4.5±1.1
serious[2]	2.6±2.1	2.6±1.4	2.7±1.3
responsible[3]	1.4±0.5	1.4±0.5	2.3±1.9
sorry[4]	3.4±1.9	4.1±2.0	3.1±1.2
embarrassed[5]	3.7±2.1	3.4±1.8	3.6±1.3

5.6.5. Comments from the participants

After completion of the questionnaire we asked the participants to write comments about their experience. Some participants said that they found the presentation interesting; some were irritated by the "incident":

- "I think the presentation was really good and insightful and I would have liked to see the venues for the 2008 games." (Condition 2, whole-face blushing)
- "Quite clever design for the mascots and the emblem, i.e. much better than the London's." (Condition 3, cheek blushing)
- "I was very irritated when there was a technical fault…" (Condition 1, non-blushing)

Some participants felt connected with the avatar:

- "I felt sorry for the virtual woman because I felt that the incident wasn't her fault. She did a pretty good job at getting me to retry the number of times I did. So I think she did alright." (Condition 2, whole-face blushing)

- “It took time for her responses to retries to get more ‘emotional’ or ‘sympathetic’, but when they did it gave me more incentive to stay put.” (Condition 2, whole-face blushing)
- “The only thing which felt a little un-natural about the character was that she made too much direct eye contact. This felt a little aggressive at first, although this decreased as she blushed more.” (Condition 2, whole-face blushing)

However others felt the opposite:

- “Perhaps a prejudice of mine is to analyse computer “personality” or “individual” too much so the guide did not seem real. However when a character has more of a background or a story, if I knew who the guide was or shy she was there, I may have identified her with more human responses.” (Condition 2, whole-face blushing)

When asked about why they have pressed the “stop” button, the participants explained:

- “I was aware that the database error was not a real problem, and thought the program might be an infinite loop.” (Condition 2, whole-face blushing)
- “It was becoming tedious.”(Condition 1, non-blushing)

Some participants who did not press the “stop” button and finished all 10 trials expressed their feelings:

- “After deciding to ‘go as far as I can’ with the retry button, I started getting very irritated (almost wanting to punch the virtual agent). Either two things would happen: I would look like a complete idiot for pressing the retry button so many times, or there would be a ‘reward’ in the end. When it was over (after the 10th retry) I felt some satisfaction to have at least persisted throughout the challenge…despite it being a ‘waste of time’. I think this is a good reflection of real-life challenges. NB: I didn’t notice if she blushed or not because I ended up being more focused on the ‘retry’ button.” (Condition 2, whole-face blushing)
- “I did not stop, despite knowing that this was intentional. Mainly out of curiosity, politeness and personal challenge to see how long I could last before giving up.” (Condition 2, whole-face blushing)

- "As the experiment continued, she showed more emotion, and I think I was staying on because the things she said were the types of things I would say if I were in her position." (Condition 2, whole-face blushing)

5.7. Discussion

The results suggest that in our experiment, participants tended to notice the cheek-blushing more than the whole-face blushing. This is in conformity with other experimental results that the majority of people (68%) described blushing as something that occurs on the cheek (Shields, Mallory et al. 1990). It is possible that because cheek-blushing only changes the colour of part of the face that it is simply more consciously noticeable than whole face blushing.

Although the experiment failed to verify our prediction that participants would withdraw later with the blushing avatar, the behavioural measurement of the "stopping time" offers valuable information of how people respond towards blushing and a useful experimental paradigm for future work. This might seem contradict to De Jong's finding that blushing serves an remediate effect (de Jong 1999; de Jong, Peters et al. 2003), however it should be noted that: in previous work only paper-based script were used to "describe" blushing, but our study used visual stimuli. Another explanation could be that only having a maximum of 10 trials was not sufficient. In any case, first, the results suggest that people who were more agreeable tended to stay in the experiment with the avatar longer, which validates our experimental setup. Secondly, it is very interesting to find a significant result that the cheek-blushing avatar is positively associated with participants withdrawing earlier. What exactly is the impact generated by cheek blushing? One possibility could be that participants felt embarrassed with the cheek-blushing and therefore withdrew earlier; but our questionnaire results suggested otherwise: the cheek blushing avatar received same level of co-presence as the non-blushing avatar, which were significantly lower than the whole-face blushing avatar. Moreover, the results of other questions also indicated a tendency of the participants to think that the whole-face blushing avatar, rather than cheek-blushing one, felt "sorrier". However, in terms of how embarrassed the participants thought the avatar was, there was no difference between the three conditions. Therefore the only

explanation we have is that the participants were less tolerant towards the cheek-blushing avatar, which is in line with De Jong's finding that there is a negative correlation between "observed blush" and the "reliability" of the blusher (de Jong, Peters et al. 2002).

A further interesting finding of this work has been the higher level of reported co-presence triggered by the whole-face blushing avatar. More importantly, participants felt a higher level of co-presence with the whole-face blushing but without consciously noticing the blushing. This suggests whole-face blushing acts at a basic pre-attentive level.

With other questions, we found a tendency of participants to trust the whole-face blushing avatar more than the others, which is consistent with De Jong's finding based on 90 participants (de Jong 1999).

5.8. Conclusions and future work

First, one of the interesting findings is that participants noticed the avatar's cheek blushing more than the whole-face blushing. Second, results of the behavioural responses suggest that the participants tended to withdraw earlier, and were therefore less tolerant if the avatar was cheek blushing. However, there was no difference between non-blushing and the whole-face blushing regarding participants' behavioural responses. This suggests that 'cheek blushing' was not convincing as a blushing response, at least it did not evoke sympathy responses, and that this type of blushing was worse than having no blushing at all.

Finally, the co-presence questionnaire indicates a strong correlation between whole-face blushing and "co-presence". However, as mentioned above, the evidence suggests that the participants were less prone to notice the whole-face blushing. This implies that the participants felt increased co-presence with a whole-face blushing avatar even though they may not have been consciously aware of the blushing.

As a very first experiment in this domain, this study maps out a field of inquiry for methods to improve the quality of interaction between people and Virtual Characters. Our fundamental measure was a behavioural one – whether or not people stopped before the end of the experiment, and this showed that cheek

blushing was not as convincing as either whole-face or no blushing. (In portrayal of Virtual Characters, it is likely to be the case that doing something wrongly is worse than not doing it at all). Connected with this was the fact that whole face blushing resulted in higher reported co-presence. This points the way for our future work to put more resources into adequate representation of whole-face blushing.

As the second experimental study in this thesis, the results provided us with evidence that male participants responded towards a female avatar differently when she expressed embarrassment. In the next Chapter, we further examine how a female avatar who expresses shyness would affect the male participants. This experiment was conducted on a desktop machine; in our next Chapter, we move back to the more immersive CAVE-like environment.

Chapter 6 Experiment: Interview with a Shy Virtual Woman

In previous Chapters we have described the interaction between male participants and (a) a forward virtual woman in a CAVE-like system, (b) a blushing female avatar on a desktop. From the results of the two experiments we have learnt that the immersive CAVE-like system provoked a high response at both physical and emotional level in the participants, which triggered realistic interactions. The desktop based experiment, although not as immersive, provided us evidence of change in participants' behaviour when interacting with a virtual woman who exhibits, or not, a facial feature related with shyness (blushing). In this Chapter, we further investigate participants' reactions towards a shy virtual woman, in the highly immersive CAVE-like system.

6.1 Motivations

A corollary of our basic thesis is that Virtual Characters should elicit responses in human participants consistent with the displayed emotional states of those characters. One of the emotional states we are interested in most is shyness, or social anxiety, as the long term goal of this research is intended to be training and rehabilitation in the context of social phobia. We are interested in the potential of creating Virtual Characters who are shy, or socially anxious, and see how this impacts the interaction between the Virtual Character and the participant.

In this Chapter, we further look into using realistic avatars in the CAVE-like system. Our goal is to explore the limits of VR, in particular the human-avatar interaction. We want to see how much do the social rules that apply in everyday life follow over to the virtual world. In particular we are interested in how much the avatar's behaviour influences the interaction. In Chapter 4 we have implemented a "positive" avatar; in this work we will implement a "shy" avatar.

In Chapter 4, the "positive" avatar managed to engage participants to a high level interaction – as the conversation went on, the participant felt less and less anxious, and responded towards the avatar as if she were real to a great extent (subjective, physiological, behavioural). In this experiment, we will push the boundary even further. We will build a "shy" avatar and see if participants will treat

her as a “shy” person. Therefore this Chapter is concerned with representation of shyness in avatars within Virtual Reality, with the goal of building avatars with different degrees of shyness. In particular, we are interested to know whether there will be different responses of people to their interaction with a shy or non-shy female avatar.

6.2 Hypothesis

First, we would like to validate our implementation, therefore our first hypothesis is: participants recognise the shy avatar as “shy”.

Secondly, we want to further investigate the boundary of changes triggered in participants’ responses by Virtual Characters in VR. We think the interaction with the shy avatar, who “worked” very hard and displayed shyness consistent with her verbal responses, would change the participants’ behaviour towards her. Therefore our second hypothesis is, participants trust the shy avatar more, would like to spend more time with her, and feel more obliged to do her a favour.

6.3 Experimental Design

6.3.1 Challenges

With the experience from our previous work, we have gained valuable knowledge in designing experimental studies. However, in order to test our hypothesis with realistic avatars in the CAVE-like system, there were still many difficulties.

We have used a realistic Virtual Character displayed on a desktop in our previous experiment (Chapter 5). In this experiment, we will use a similar Virtual Character in a CAVE-like system, rather than from the “online agent” type of avatar we used in our previous experiment. In the setup of this experiment, a higher level of interaction is required. With our previous desktop “online agent”, the focus was on facial expression, whereas in the CAVE-like system there are more factors to consider, including gaze, full body movement, and maintaining a social distance with the participants (proxemics).

In our first experiment (Chapter 3) we have gained experience in using Virtual Characters in the CAVE-like system. However the complexity of our previous

implementation, in line with the state-of-art technology at the time of year 2005, was obviously outdated. With the rapid growth of graphic hardware and software, avatars with high visual fidelity have become more common. Therefore to match participants' expectation and achieve more realistic interaction in Virtual Environment, we needed to adapt to the high visual fidelity standard by updating our experiment with more complex avatars.

Another problem then emerged: to achieve the desired immersive interaction, it was important to maintain the consistency between the realism of avatar behaviour and appearance (Vinayagamoorthy, Gillies et al. 2006). Therefore our traditional hand animation for body movement and facial expression with our cartoon-like avatars would not be appropriate with our updated more complex and realistic avatar. To achieve high level of realism in behaviour, in this experiment, we have used motion captured data to animate our Virtual Character.

In our experiment, using motion captured data would increase the avatar's behavioural realism. In the following Sections we present the design of the experiment. We present the implementation including a detailed procedure of motion capture in Chapter 3 (see Chapter 3.2).

6.3.2 Scenario

Before the experiment, the participant was given the SAD questionnaire (see Section 2.5) which included 27 statements associated with social anxiety, which he could choose either to "agree" or "disagree". Following are three questions from the questionnaire:

(1) I usually feel relaxed when I meet someone for the first time.

(2) I try to avoid formal social occasions.

(3) I often feel on edge when I talk to a group of people.

The overall score reflected the participants social anxiety level, which was calculated with each choice they made as well as the logic of the statement, for instance, choosing "disagree" of statement (1) or "agree" to statement (2) and (3) would add 1 to their social anxiety score.

Then the participant was told that we were going to test certain aspects of our Virtual Reality system, and his task was to interview a virtual human following a set script. After being introduced into the scenario, the participant was seated at a table on top of which was a laptop. After waiting in the scenario for a couple of minutes, the participant heard some noises played from outside the CAVE – a conversation between a male authority figure and a female, who apparently was too shy to enter the room (or in the controlled condition the context is the same, but the voice sounded slightly annoyed rather than shy). Eventually the female agreed in going in for the interview. The conversation was as following: (A: Authority figure, F: Female)

A: Ok, your turn now! Are you ready?
F: Do I really, have to go through this?
A: I'm afraid yes! As we have agreed!
F: But I'm not…
A: Oh come on, he is here already! Waiting for you! Go in and sit there! Quick!
F: o…k… (coughing, steps)

The female avatar, Jenny, then walked into the scenario (see Figure 6.1). After introducing herself, the participant started reading the instructions from the laptop. The following is an extract from a typical conversation (the full script see Appendix E): (Jenny – J; Participant – P)

J: Hi.
P: Hi, what's your name?
J: I'm Jenny, nice to meet you.
P: Nice to meet you too.
J: Shall we start?
P: Sure. (Read instructions from the laptop) The reason for seeing you, Jenny, is that I need to go through a questionnaire with you, to assess your feelings in interactions with people. This is part of a long series of studies that we have been doing on social relationships, and your answers will be very helpful for us.
J: OK

P: Good.(Read from the laptop). There will be 27 questions to answer, and the total time will be about 5 minutes. Here is an example: I would make a statement such as: "You feel relaxed even in unfamiliar social situations" and then you should respond "I agree" or "I do not agree" – it is that simple.

J: I see.

P: (Read from the laptop). We just go through these questions one by one until we have finished. I'm sorry I am reading out these instructions Jenny but it is important that we say exactly the same things to everyone.

J: It's ok.

P: (Read from the laptop) Do you realise Jenny that the answers you give will be completely confidential, and that we will only refer to them in statistical form?

J: So I've been told. Why do you keep using my name, it is like you're trying to sell me something.

P: I'm sorry…but… Anyway, shall we do a rehearsal now?

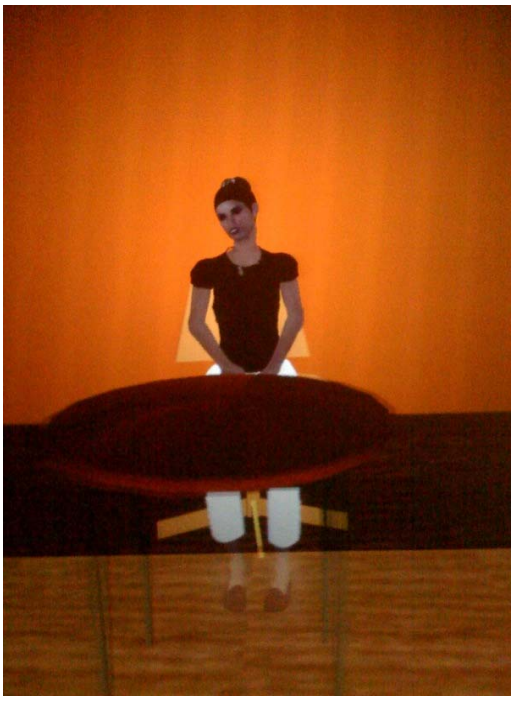


Figure 6.1 The Scenario

The participant then started read out questions from the laptop. The questions, as were already known to the participant, were exactly the same as one of the questionnaires (SAD) that the participant had completed earlier. The only difference was instead of using "*I* try to avoid formal social occasions", the statement were changed to "*You* try to avoid formal social occasions". Every time after the participant asked the avatar a question, he looked at the avatar and waited for her to answer. He then had to put her answer on the laptop in order to proceed to the next one. The participant was also told that after reading each question from the laptop he should be looking at the avatar when expecting an answer from her. The avatar answered every question, sometimes after a small pause, sometimes she acted as if she was having problems answering the questions, and sometimes she

asked the participant to repeat the questions. An example extract conversation is as following: (Jenny – J; Participant – P)

P: You usually feel calm and comfortable in social situations.

J: No, I disagree.

P: You are usually at ease when talking to someone of the opposite sex.

J: Say it again?

P: OK. You are usually at ease when talking to someone of the opposite sex.

J: Oh, do, do I have to answer this question?

P: Ah, it will be very helpful if you do…and don't worry it's totally confidential.

J: Eh (Pause), I disagree.

There were two conditions for the experiment. In the first condition, the avatar carried out behaviours and had a tone of voice that indicated shyness. In the second condition the avatar carried out behaviour and with a tone of voice that indicated social confidence. In both cases the avatar responded with the same answers, and the content of the answers to the questionnaire always indicated that she was extremely shy (i.e., even the non-shy avatar answered the questions with answers that suggested social anxiety – even though it was clear that in fact she was not socially anxious). In both conditions the movements of the avatar were animated through motion captured data performed by the same actress. The voice for both conditions was recorded the same time as the motion capture session. For a detailed description of the implementation please see Section 3.2.

In the case of the shy avatar she appeared to be very embarrassed, and only with significant effort does she managed to answer all the questions. In the control condition the avatar said the same things but because she displayed non-shy behaviour with a non-shy tone of voice she might appear to be untrustworthy. She accomplished the task with no obvious effort, and her behaviour did not match her answers to the questionnaire.

The interview lasted about 10 minutes. At the end the avatar displayed relief and asked if the participant could do her a favour in return. She then asked the participant to fill in the questionnaire which was displayed on the laptop in front of him, and told him that she would go through the answers with him later. The

participant started answering the questions (by choosing options on the screen) and it was clear that the questions were an evaluation of the Virtual Character herself (for example, how much would the participant like to meet her again?). At this moment a phone from the outside started ringing; she apologised and told the participant that she had to leave to answer the phone. She pointed to a small bell on the desk at which the participant was seated and told him to ring the bell to call her when he had finished the questionnaire, and then she stood up and quickly left. The participant could hear her picking up the phone and talking, quietly in the background.

The participant was left alone in the scenario to finish the questionnaire. However, the avatar did not return. We expected that the participant would then ring the bell. However, she still did not return. He might ring the bell again, and again, until he would decide to give up. The experiment ended when the participant decided to stop and left the Cave, or if he or she started calling the experimenter. Otherwise 10 minutes after the participant finished the questionnaire, the experimenter opened the curtain and apologised to the participant. She explained to the participant that the avatar would not return to the scenario.

6.3.3 Materials

The experiment was carried out in the CAVE-like system, and the participants were fitted with head tracking and a pair of 3D stereo glasses, as described in the experimental study in Chapter 4 (see Section 4.3.1 Materials).

The scenario was implemented with XVR and PIAVCA, and the Virtual Character animated with motion captured data. For implementation detail please see Chapter 3 (Section 3.2 Animation Virtual Characters with Motion Captured Data).

6.3.4 Factorial Design

Table 6.1 Factorial Design (n=12)

	Participants
Shy avatar (condition1)	n
Non-shy avatar (condition1)	n

As shown in Table 6.1, it is a 2-condition between groups factorial design. In condition 1, the avatar behaves very shy, and looks like she's making a big effect in the interview with the participant; in condition 2 (control condition), the avatar says exactly the same thing, but behaves as if she is very confident, and yet a bit aggressive.

Both conditions will be recorded with the same actress with our motion capture system, which will then be applied to our Virtual Characters as body movement.

6.4 Pilot Studies

Experimental studies are often costly and time consuming, especially when human participants are involved, since too many variables are included in such experiments. Pilot studies are crucial in such experimental studies since they can help to identify experimental design flaws, at the same time prepare the experimenter for different situations.

In the preparation of this experiment we have carried out two sets of pilot studies. In the first round of the pilot study, we have recorded trial motion captured data. Then we have run 10 pilot studies, with which we have updated our script, including adding clear instructions in the end of the scrip, making the avatar's answers more consistent (to be able to indicate strong shyness from her answers), and adding extra backup lines for unpredictable situations (i.e. "Never mind", "What's the next question?", and "Let's just carry on"). We have also learnt that the most participants who interacted with the shy avatar identified her as shy, and those who interacted with the non-shy avatar had a negative opinion of her.

With our finalised script we have then recorded a formal motion capture session with a professional actress. With the new motion captured data we ran a further 4 pilots, 2 on each condition, with the full procedure including filling questionnaires. These experiments further helped us become familiar with the procedure of the experiment, making sure the experimenter said the same thing and followed exactly the same routine for every participant thus avoiding introducing extra variables.

6.5 Measurement

6.5.1 Questionnaire Measurement

Data were collected by questionnaires (as attached in the appendices) as follows:

(a) A pre questionnaire to record basic information such as age, gender, status, and prior experience of Virtual Reality and computer games.

(b) A standard pre-questionnaire to assess their personality (NEO)

(c) A standard pre-questionnaire to assess their social anxiety level (SAD)

(d) A questionnaire given during the experiment to assess their feelings towards their virtual interviewee.

(e) A post experience standard questionnaire to assess their degree of presence in the Virtual Reality (SUS).

6.5.2 Behavioural measurement

In addition, the length of time participants choose to wait for the avatar to return, the first time the participant rings the recall bell, the number of bell rings, together with their behaviour while waiting, will be recorded as part of the assessment of their responses. All participants will be video recorded during the experiment, given permission from the consent form.

6.6 Procedures

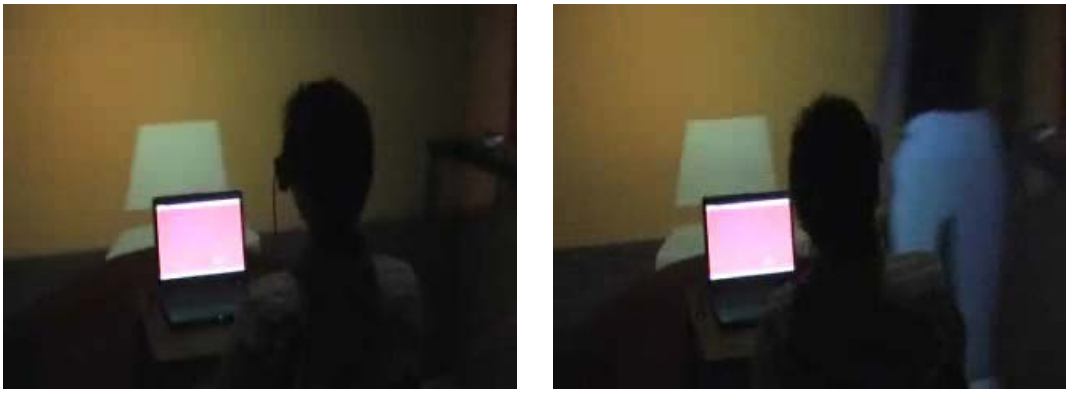
6.6.1 Recruitment

Participants were recruited through emails around UCL and also from the UCL Psychology Subject Pool (it's a website with open access to everybody in the public interested in doing experimental studies, among them most are students in London). Twenty-four participants attended our study, with the average age 27 (20 -62), of which 6 undergraduate students, 9 master students, 4 PhD students, and 1 university staff. The rest are 1 actor, 1 teacher, and 2 work as casual labour. They arrived at the CAVE at a pre-arranged time. All participants are fluent in English. The study was approved by UCL Ethics Committee.

6.6.2 Procedure

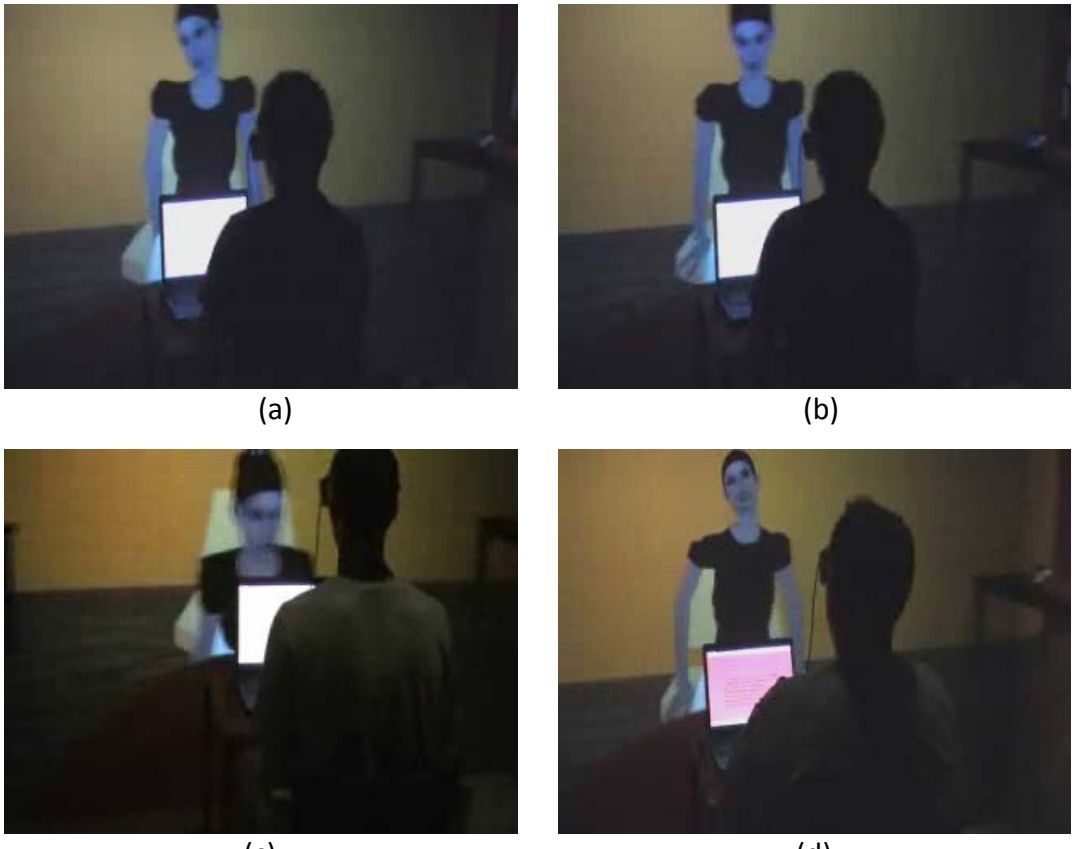
Participants attended the experiment at pre-arranged times. Upon arriving, the participants were given an information sheet to read, and if they agreed to continue with the experiment, they were given a consent form to sign. The experimenter then gave them a computer based pre-questionnaire asking information such as age, occupation, etc. They were also given another two standard questionnaires (SAD, NEO), also computer based, designed to assess their personality traits and their comfort in everyday social interactions. The participants were told both in writing and verbally that their task was to carry out an interview in order to help us assess our interview training system. They were also informed that they would receive step by step instructions. After this, the participants put on stereo glasses and entered into the Virtual Reality Cave-like system in UCL Computer Science. In the Cave they were seated in front of a physical table on which there is a laptop and a small bell. Then the experimenter again explained that their task was to carry out an interview, and demonstrated to the participants how all of the instructions and all of the interview questions could be seen on the laptop on the desk at which they are seated. After finally checking that everything was understood, the experimenter left the participants in the Cave by themselves.

The participants were waiting in the CAVE for 2 minutes with background music, during which we video-recorded their body movement from behind (See Figure 6.2 (a)). Then the female avatar walked into the scenario (See Figure 6.2 (b)), and sat down. After introducing herself, the participant started reading the instructions, and read out questions from the laptop. The questions, as already known to the participant, were exactly the same as one of the questionnaires (SAD) that the participant had completed earlier. During the interview the avatar behaved either shyly (See Figure 6.3 (a), (b)) or confidently (Figure 6.3 (c), (d)). After the interview, the avatar left the participant to wait, but never come back. The experimenter eventually terminated the experiment when the participants stepped out of the CAVE, called the experimenter's name, or after the avatar has left the scene for 10 minutes.



(a) (b)

Figure 6.2: (a) Participant waiting in the CAVE (baseline) until (b) the avatar entres the scenairo.



(a) (b)

(c) (d)

Figure 6.3: (a) and (b) Participant interacts with the shy avatar who displays a closed posture with her head lowered down. (c) and (d) Participant interacts with the non-shy avatar who displays a dominant posture by expanding her body, raising her head, and leaning towards the participant.

After the experiment, participants were given a post-questionnaire and a short interview. In the end, the experimenter explained to the participants the design and

the actual purpose of the experiment. The whole script including the off scene voice in the beginning is attached as Appendix E.

6.7 Results

During the experiment behavioural responses and questionnaires were used as measurements. In this Section we present the results from both. Starting with behavioural responses (Section 6.7.1), we then present the results of the questionnaire participants did during the experiment (Section 6.7.2), and the questionnaire they did after the experiment (Section 6.7.3).

6.7.1 Behaviour Responses

At the end of the experiment, the avatar left the participant to do a questionnaire on his own, and never come back. The participant was given a bell to ring to call the avatar back. We measured their behaviour responses while waiting.

During the time the participants were waiting in the CAVE, their behaviour was recorded by a camera from behind. We went through the recorded video clips and have abstracted two features: (a) after the avatar left the scene, how many seconds they have waited until the first time they rang the bell. (b) After the avatar left the scene, how long they have waited until the experiment is terminated. Figure 6.4 shows the mean time and standard error of each behavioural measurement, as well as the difference between the two, as it shows how long participants waited after the first time they rang the bell until the experiment is terminated. As shown on the diagram, there is no significant difference between the two groups.

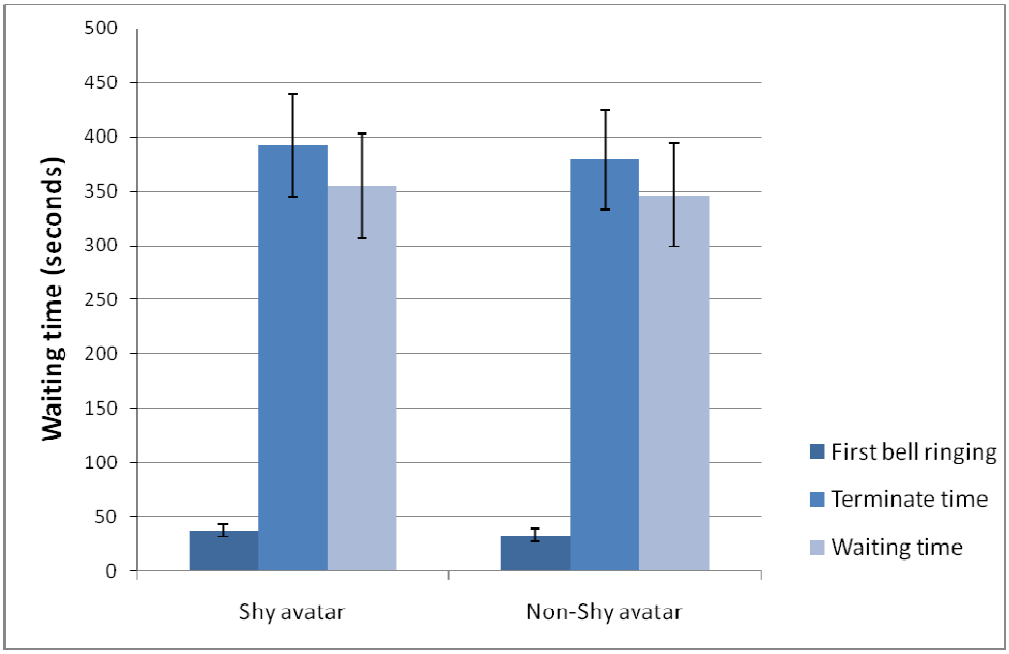


Figure 6.4: The time (in seconds) participants spent before ringing the bell, terminating the experiment, and the time they have waited. There is no significant difference between the two groups.

We have also categorised each participant's waiting time into 3 groups: group A includes participants who have waited until the end of the 10 minutes trial time; group B include those who terminated the experiment by either calling the experimenter or standing up, but have waited longer than 5 minutes; group C includes those terminated within 5 minutes. Table 6.2 shows the result of the number of participants in each catergory, with each condition. Again, no significant difference was found with the behavioural measurement.

Table 6.2: The number of participants in each catergory, as defined by the time they spent on waiting. Still there is no significant difference.

	Group A (t>=10min)	Group B (5min<t<10min)	Group C (t<=5min)
Condition 1 (shy)	2	4	6
Condition 2 (non-shy)	3	5	4

6.7.2 How did they think about Jenny?

Towards the end of the interaction with the avatar, the participants were requested, by the avatar, to fill in a questionnaire regarding the feelings towards "Jenny". In this Section we present the results of the questionnaire the participants filled in during the experiment.

There were 8 statements on the questionnaire regarding the participants' general feelings towards "interviewee", i.e. "***I liked the interviewee***", or "*I* ***would like to spend more time with the interviewee.***" The participants had to choose either agree or disagree with each question. Table 6.3 shows the proportion and standard deviation of the number of "agrees" for each statement with each Condition.

Table 6.3: The proportion and standard deviation of "agree" for each statement in the questionnaire the participants filled in during the experiment.

Statement	**The proportion of participants who have agreed**	
	Condition 1 (shy)	**Condition 2(non-shy)**
I liked the interviewee.	0.83	0.5
I would like to spend more time with the interviewee.	0.83	0.33
I feel the interviewee is reliable.	0.58	0.5
I feel the interviewee is honest.	0.92	0.92
I feel the interviewee is sociable.	0.17	0.17
I feel the interviewee is friendly.	0.67	0.42
I feel the interviewee is sympathetic.	0.67	0.33
I feel the interviewee is trustworthy.	0.83	0.5

We carried out a binomial logistic regression with each statement as the dependent variable, and condition as the independent variable, and found for the second statement, "**I would like to spend more time with the interviewee**" , condition 2 has a lower proportion than condition 1 with significance level P = 0.03, as shown in Table 6.4. This suggests the participants, after interacting with the shy avatar, were more likely to choose to spend a bit more time with the avatar.

Table 6.4: Binomial Logistic Regression of "more time" (1 if the participant agree to spend more time with the avatar and 0 otherwise). Condition 1 is subsumed under the constant term, and the coefficient for Condition 2 is difference from Condition 1.

Term	Coefficient	P
Constant	0.97	
Condition 2 (non-shy)	-1.40	0.03

We have also examined the answers of all questions as a whole: we compare the difference between the proportions of participants who chose "agree" overall for each condition, as shown in Table 6.5. A test for the difference between two proportions rejected that the two proportions are the same, at the level of 0.05 ($z = 3.21 > 1.96$). Therefore, with the shy avatar participants gave more positive answers in this questionnaire.

Table 6.5: Proportions of "agree" for both conditions and the overall sample. A test for the difference between two proportions rejected that the two proportions are the same, at the level of 0.05 ($z = 3.21 > 1.96$).

	Number of "Agree"	Overall sample	Proportion
Condition 1 (shy)	66	96	0.6875
Condition 2 (non-shy)	44	96	0.4583

6.7.3 Presence Questionnaire

Immediately after the experiment, the participant was given a presence questionnaire (see Appendix E), on which the participants had to choose a scale between 1 to7 as their experience towards: their general experience (Question 3-6, 8, where question 6 and 8 have the rating inversed), their responses towards the "place" (Question 10-14), or their responses towards the virtual lady (Question 15, 17-19). We expected no difference between the two conditions of the presence scores.

Table 6.6 shows the average value and standard deviation of the results regarding each category, together with sample questions belongs to the category. No significant results were found.

Table 6.6: The average value and standard deviation of Presence Questionnaire.

Category	Average Value and Standard Deviation	
	Condition1 (shy)	Condition 2 (non-shy)
General Experience Example: To what extent were there times during the experience when the interview was the reality for you? at no time 1 2 3 4 5 6 7 almost all the time	3.75±1.73	3.95±1.66
Responses towards the "Place" Example: How much did you behave within the interview as if the situation were real? not at all 1 2 3 4 5 6 7 very much	5.08±1.47	4.68±1.38
Responses towards the Virtual Lady Example: How much was your emotional response to the interviewee as if he/she were real? not at all 1 2 3 4 5 6 7 very much	4.41±1.76	4.27±1.58

6.7.4 Summary

Although during the experiments we have observed that the avatars personality did have a strong impact on the interaction with the participants, no evidence has been found with our behavioural measurement. On the other hand the questionnaire result did provide us some evidence to justify our hypothesis is that more participants expressed that they would like to spend more time with the shy avatar, and gave more positive comments about her. At that same time, the presence questionnaire suggests no difference which confirms that the two conditions were the same as far as this was concerned. In order to gather more information for a better understanding of the results, in the next Section we carry out a thorough analysis on participants' comments and the interview data.

6.8 Comments and Interviews

Immediately after the experiment, the participants were given a post-questionnaire, at the end of which they were asked to leave some comments on their experience. Upon finishing the questionnaire, the experimenter conducted a short interview with the participants to further discuss their feelings during the experiment. This Section presents the summary and discussion based on the comments and interview data.

6.8.1 Comments

In the end of the Presence Questionnaire the participants were asked to leave some comments, in particular:

- Aspects of the experience that made you respond as if it were real.
- Aspects of the experience that led you to make responses that would have been unrealistic if the situation depicted had been occurring in reality.
- Aspects of the situation that suddenly disturbed your experience of being in the interview.
- Aspects of the experience that helped or hindered you achieving your task.
- Aspects of your feelings towards the experience

In those comments some of them described they were surprised by how realistic the feelings were:

- "When she first walked past me I had a sort of mental shiver – a very weird surreal feeling as if I was next to an alien or something, but that quickly passed. Otherwise the whole experience was very real, and I was surprised at my emotional response to the character." (Condition 1: Shy Avatar)

Some were very disturbed by her:

- "Certainly she was very horrible looking, and when she leaned forward over the laptop screen, or extended her hand towards me, I recoiled. At the same time she had a sexual allure, it was also very disturbing when she came into the room from behind, even thought I was expecting (the avatar's) entry from that direction." (Condition 2: Non-shy avatar)

- “The interviewee was sitting, quite close, especially when she leant forward, something that was strangely discomforting as I knew she wasn’t real.” (Condition 2: Non-shy avatar)

Some participants pointed out aspects that made them particularly feel Jenny was real:

- “I liked the mixed responses of the interviewee and the fact that they gave opinions. It made them seem more real.” (Condition 2: Non-shy avatar)
- “Interviewee’s comment about my repeating of her name was an interesting way to give a momentary illusion of her being a person.” (Condition 2: Non-shy avatar)
- “I could sense by the answers she was giving that she was uncomfortable with situation and wasn’t relaxed. This made the whole scenario feel even more lifelike and made me feel uncomfortable as well.” (Condition 2: Non-shy avatar)
- “I responded as if the interview was real more at the points where the interviewee asks questions (especially unexpected). This was also true (to a lesser degree) when answers to questions were more elaborate.” (Condition 2: Non-shy avatar)
- “Thought Jenny played being nervous very well.” (Condition 1: Shy avatar)
- “The experience felt real because the body language of the interviewee was realistic and in turn my body language responded.” (Condition 2: Non-shy avatar)

Participants were also asked to point out aspects of the experience that made them feel less realistic:

- “I thought when Jenny suddenly had a phone call and left, that was a little bit unrealistic.” (Condition 2: Non-shy avatar)
- “Unrealistic in this sense: the end of the interview, where I was suddenly told that I would be interviewed, was surprising and slightly disturbing.” (Condition 2: Non-shy avatar)
- “Thought Jenny was too unsociable.” (Condition 1: Shy avatar)

6.8.2 Interviews

The interviews with the participants were conducted after they finished the experiment and the post-experiment questionnaires. Each interview lasts about 5 to 10 minutes. The outline of the interview is:

1. Regarding the interview you had with Jenny, did you enjoy the experience?
2. There was a questionnaire you did with Jenny in the end. When you did it you might think Jenny would come back and go through the answers together with you, so you might have concerns while doing it. Now let's go through the questions again, but I would like your true opinion, it doesn't need to be the same as the answers you gave there.
    a. Did you like Jenny?
    b. Would you like to spend a bit more time with her?
    c. Do you think she's a reliable person?
    d. Do you think she's honest?
    e. Do you think she's sociable?
    f. Do you think she was friendly?
    g. Do you think she's sympathetic?
3. If you were going to describe Jenny to a friend, what kind of word would you use? Her personality?
4. During the interview, did you feel quite relaxed, or anxious and stressful?

The experimenter who conducted the interview followed the outline, but was not restricted to its sequence and content. Here we report the few key points as listed on the outline, separated by participants who interacted with the shy avatar and participants who interacted with the non-shy avatar, followed by a small summary at the end of each condition.

6.8.2.1 Condition 1 (Shy avatar, 12 participants):

From the interview:

1. Did you enjoy the experience?

When asked if they have enjoyed the experiment, the majority (7 out of 12) responded with positive feedback, 4 participants thought it was "ok" or feels "neutral" about it. One participant said "*I kept forgetting the* fact *that she wasn't actually real, and I kept on having to remind myself that she wasn't real and I go*

back and forth". Only one participant said he didn't like it because "*I felt she was **unsociable**, and **rude**... she doesn't like talking to group of people … she doesn't introduce people.*"

2. Questions regarding how they feel about Jenny:

a. Did you like Jenny?

Most of the participants either said they liked her, or they felt neutral. Typical answers from the participants who felt neutral towards her were "*Yeah, she seemed OK. There is nothing...yeah, she seemed quite OK,*" or "*En, generally I don't dislike her, so, say I like*."

Two participants answered they didn't like her, one explained: "*She seemed...I don't feel I was warmed by her. She seemed pleasant enough, but she just seemed she has a bit of the attitude.*"

b. Would you like to spend a bit more time with Jenny?

Similar to the previous question, the majority of the participants either showed a neutral attitude towards this question or said they would like to spend a bit more time with Jenny, because "*It sounds like she's quite sociable, well, not that sociable, but sounds like she's a nice person to talk to.*"

However, 4 participants expressed they wouldn't like it, because *"…She's not very happy is she? Obviously, like, again, I feel weird now. Cause I'm talking as if she was a real person. In that situation she was obviously uncomfortable, because she was not very sociable. "*

c. Do you think she's a reliable person?

Among the 12 participants, 8 thought the avatar was reliable or said they felt neutral about it, one explained "*I don't know...it probably goes hand to hand of her honesty, because some of the questions she has answered honestly.*" The other 4 felt she's not reliable, because "*from her answers to the questions she was very anti-social. Anti-social people tend to be less reliable.*"

One participant who thought she was not reliable further explained: "*It's just she's the type of person that I think just has a lot of difficulties in her life. And that can kind of play with, how do I put this, it can create a lot of emotional disturbance. And I think most of the disturbance can kind of make a person behave differently*

from how maybe they would normally behave if they were happier. So it might make her do things that she doesn't want to do."

d. Do you think she was honest?

Ten participants thought she was reliable or "fairly reliable" because "*she was saying she was not a very sociable person. Normally people don't mention that*."

Two people thought she wasn't honest, both of them thought she wasn't reliable.

e. Do you think she was sociable?

Out of 12 participants, 11 thought she was NOT sociable. Only 1 thinks she is "*Modestly*" sociable because she "*answered the questions. Although she was a bit hesitating, I'd say she's reasonably sociable at circumstances.*"

f. Do you think she was friendly?

Nine participants thought she was friendly or "*not unfriendly*", the other 3 thought she wasn't friendly because "*She's not sociable so she cannot be friendly*."

g. Do you think she's sympathetic?

Nine participants thought she was sympathetic or they felt neutral. One participant explained: "*…because she is honest enough to express her, inadequacies, maybe she has that capacity…*" Two participants thought she wasn't sympathetic.

h. Do you think she's trustworthy?

Ten participants thought she was trustworthy. The other two thought she was not trustworthy, both of them also thought she wasn't reliable (but not both of them thought she was dishonest) and one explained: *"…I think somebody who has a lot of inner problems, again, they can behave differently from how they might normally behave if they were healthy, if they were emotionally or mentally stable.*"

3. If you were going to describe Jenny to a friend, what kind of word would you use? Her personality?

Personalities mentioned here include: Shy (4 participants mentioned it directly), very emotional, hesitant, artistic, and introverted.

4. During the interview, did you feel quite relaxed, or anxious and stressful?

Most participants said they felt quite relaxed, One participant said it was very stressful because the avatar's emotion made him uncomfortable.

To conclude, from the interview with participants who interacted with the shy avatar, the majority of the participants seemed to have enjoyed the relaxing experience, and liked Jenny, or at least had a neutral attitude about the interaction. Most of them also found Jenny honest, and trustworthy. However, when it comes to the question about Jenny's reliability, many people hesitated. Some answered straight away that she's not reliable, because of her shyness or social incapability. The majority of the participant also thought Jenny was not sociable. Almost all participants described her with many words related to shyness, including: shy, introverted, embarrassed, and nervous.

The interview with the participants showed that, they thought Jenny was a likable person, very shy, not sociable, honest, trustworthy, but they are not sure if she's reliable. Most of them enjoyed the interaction and felt relaxed during the interview.

6.8.2.2 Condition 2 (Non-shy avatar, 12 participants):

1. **Did you enjoy the experience?**

About half of the participants said they enjoyed it, because it was "*interesting*". The other half said they didn't like the experience, reasons given including: "*I felt the woman was horrible*", "*in a normal situation, I would be uncomfortable interviewing someone like that*", and "*The person seemed very negative.*"

2. **Questions regarding how they feel about Jenny:**

a. **Did you like Jenny?**

Almost everybody but three said they didn't like Jenny, because she was "*inconsiderate*", "*cold*", and "*hostile*". One participant commented "*I didn't like her as a person but I felt sorry for her*".

b. **Would you like to spend a bit more time with her?**

Most of the participants said without hesitation that they would not like to spend more time with her, because she "*makes me feel uncomfortable as I was asking her these questions*", and "*She seemed a bit aggressive*".

One participant commented "*I would be interested in sort of continuing that interview…I'm not sure if she would remain like that…She's obviously some kind of awkward. But I think she would probably improve once she's getting to know someone.*"

c. Do you think she's a reliable person?

About half of the participants thought she was reliable because she was "*honest*", and "*she answered truthfully*". Participants who thought she wasn't reliable explained as "*she said she doesn't usually go to* social *engagement*".

d. Do you think she's honest?

The majority of the participants thought she was honest, because: "*a lot of the questions she gave I felt were her honest opinion*", "*She was genuinely giving answers that weren't easier answers to give*", "*she was very direct about things*", "*I didn't see any hints of a lying personality*".

However, one participant who thought she's not honest because "*her body language conflicted with her answers*".

e. Do you think she's sociable?

Most of the participants thought she wasn't sociable, judging from her "*answers*", as well as her "*unwillingness*" to attend the interview.

f. Do you think she was friendly?

About a third of the participants thought she was friendly, because "*she was open*". The rest thought she was unfriendly because she was "*rude*". One participant thought she could be friendly "*if she wants to be*".

g. Do you think she's sympathetic?

About half of the participants found her sympathetic, the other half thought otherwise.

h. Do you think she's trustworthy?

Similar to the pervious question, some participants found her trustworthy and some didn't. For those who thought she was trustworthy, one of them explained: "*In a sense that she doesn't lie, I guess she's trustworthy*".

3. If you were going to describe Jenny to a friend, what kind of word would you use? Her personality?

Regarding Jenny's personality, many words were mentioned during the interview, including: inconsiderate, rude, impatient, false, potentially manipulative, common, working class, slimy, unsympathetic, blunt, cold, annoyed, direct, straight forward, and negative.

4. During the interview, did you feel quite relaxed, or anxious and stressful?

Half of the participants found the interaction was stressful, because "*she felt uncomfortable*" and "*I felt negative remarks*". Some participants also mentioned they felt anxious in particular when the avatar leaned towards them.

To conclude, unlike the previous situation, it was not as an enjoyable experience for the participants, and most of them didn't like Jenny, neither would they want to spend more time with her unless it's out of "*curiosity*". Some participants thought she was reliable because she was open. Similarly to the previous situation, most participants thought she was honest, but not sociable. Another different point from the interaction with the shy avatar is that, after interacting with the non-shy avatar, half of the participants found the interaction stressful.

6.9 Discussion

As we predicted, the results from the Presence Questionnaire showed no difference in how the participants felt about the interaction. However, in the questionnaire participants filled in during the experiment, there was evidence suggesting that participants who interacted with the shy avatar were more positive about her personality and were more likely to choose to spend a bit more time with her, which coincides with our prediction. Nevertheless, although on questionnaire participants expressed their willingness to spend longer time after interacting with the shy avatar, the same trend didn't appear in their behaviour: unlike what we have predicted, there was no evidence supporting our assumption regarding the change of participants' waiting time after interacting with a shy or non-shy avatar.

It is interesting to uncover this conflict between our questionnaire results and behaviour data. The reason behind this could be that the participants chose to agree on spending more time with the shy avatar out of "politeness", which does not reflect their true opinion. The interview data helped us further investigate if this was the reason to explain this conflict.

In the interview, when asked if they would like to spend more time with the avatar, the responses of participants from the two groups were very different. In condition 1 (shy avatar) most participants were neutral towards this question, 4 participants (rather than 2 on the questionnaire) disagreed. Whereas in condition 2 (non-shy avatar), most participants responded with a negative answer without

hesitation to this question; and very few participants expressed their interest in continuing the interaction with the avatar because they were “curious”. The interview data definitely pointed to the possibility that, in condition 1, rather than being willing to interact with the shy avatar, the participants decided to respond politely to this question in the questionnaire; in condition 2, because the avatar was being “rude”, participants felt less need to be “polite” towards her.

Another interesting finding on the questionnaire, which also went against our predictions, was that there was no difference in how reliable the participants found the avatar, whether she is shy or not. Again, going through the interview data gave us an explanation: the most frequently mentioned reason for not judging Jenny as reliable was that she is anti-social. Many participants said directly that they thought people who were not sociable were not reliable. This is something we failed to recognise in the design of the experiment.

6.10 Conclusions

In this experimental study we have looked into using realistic Virtual Characters in an interaction using a CAVE-like system. We animated the avatar with motion capture data. Our first target was to implement a Virtual Character who behaved shyly. From the interview data, we’ve found among participants who interacted with the shy avatar that many words related to shyness were mentioned. Shyness was obviously identified by most participants. However, participants’ comments also suggested that the avatar lacked facial expressions and eye movements.

Our second hypothesis was that shy avatar, who gave more consistent answers, would gain more trust from the participants and make them feel more obliged to do her a favour in return. However, no difference was found in our behavioural measurement (waiting time) between the two conditions. Nevertheless, our questionnaire results indicated that participants agreed to spend more time with the shy avatar. From our interview data we’ve further identified that more participants tended to be “polite” when judging the shy avatar.

Although our original behavioural measurement did not provide enough evidence to differentiate participants’ behaviours towards the shy avatar from the non-shy avatar, we still found very interesting results from how participants

responded towards each type. As the realism of avatars becomes greater, the interaction between human and avatar becomes more complex. This experiment, especially the interview data, opened an interesting research avenue through which we may carry out our future research.

Chapter 7 Conclusions

Virtual Characters have been proven to serve a very important role in Virtual Reality (Vinayagamoorthy, Gillies et al. 2006). They are employed in the interaction between people and the Virtual Environment because they can provoke the automatic responses of users and therefore achieve more natural interaction, through language, facial expressions, gaze, and body movements. In such interactions, the change in the behaviour of the avatars has an influence on the human participants (Slater and Usoh 1994; Slater, Usoh et al. 1995; Uno and Slater 1997), and that they respond towards the avatar at an emotional, physiological, and behavioural level. In particular, when interacting with avatars, human participants, especially the shy ones, experience some level of anxiety similar to real life. In the context of exposure therapy, such anxiety triggered by avatars has a potential to be used in psychotherapy for social phobia: those who suffer from extreme anxiety while interacting with people and therefore shy away from society.

Virtual Characters interact with people through different channels: language, face, body, and others. In this research we focused on facial expression and body movement.

For facial expressions, we explored a method for expressing complex mental states using motion graphs, which was created based on data extracted from video recordings performed by actors (Chapter 3). More importantly, we have conducted an experimental study on participants' responses towards blushing – a facial feature tightly related to shyness and social anxiety (Chapter 5).

We also studied the body from two aspects: first, we examined participants' bodily responses towards the avatars, which reflect their anxiety and level of involvement (Chapter 4); secondly, we studied a method of using motion captured data to animate avatars' body movements with the target of representing shyness in Virtual Reality (Chapter 3 and Chapter 6).

The main focus of this research is experimental studies on human's reaction towards Virtual Characters. Section 7.1 to Section 7.3 summarise the three

experiments carried out in our study. Section 7.4 spells out the contributions and limitations. Finally, in Section 7.5 we summarise the experiments and discuss the future work for this thesis.

7.1 Experiment: Real Man Meets Virtual Woman

Figure 7.1: Experiment: Real Man Meets Virtual Woman

As our first experiment we carried out a study on male participants' reactions towards a forward virtual woman. We were interested in whether shy participants would experience similar levels of anxiety as in real life, and whether confident participants would enjoy the experience.

As the criteria to select socially shy and confident participants we have used the SPAI questionnaire, one of the standard instruments to assess social anxiety. This questionnaire was originally developed in 1989 with various studies some of which using over a hundred participants, and is thereafter widely used in psychological studies related with social anxiety (Herbert, Hope et al. 1992; Hewitt, Flett et al. 2003). This questionnaire, used in evaluating participants' real life interpersonal communication, was also adapted as the post-experiment questionnaire in our experiment to assess the interaction between the human participant and the Virtual Character. The result has indicated that there was a strong association between the anxiety experienced by the participants regarding their interaction with the virtual lady and their everyday life social anxiety. Together with questionnaire data, we have also included physiological data and body movement data in our evaluation. In the research of real life psychology, it is typical to have a combined measurement of all three methods (questionnaire, physiology, and body movement data) or a

selection of two for evaluation of social anxiety (Monti, Boice et al. 1984; Fydrich, Chambless et al. 1998). The results from those measurements show that participants responded towards the virtual lady as one would expect in real life, namely, their subjective responses, physiological response, and behavioural responses. While we have no exact data for real-life situations to compare to, we believe people responded as if it were real.

The result also suggested that the shy participants had a higher level of anxiety during the interaction; however, their anxiety levels were lower during the interaction than their anxiety levels in everyday life. This result could be generalised into other type of avatars or scenarios.

This study provided evidence for the potential of using Virtual Characters in psychotherapy for social phobia. In future, other virtual social encounters could also be created to further investigate the anxiety triggered in human-avatar interaction. In our study, we focused on the anxiety people have towards the opposite sex. In addition, other social relationships including interactions with authority figures, a large group, or strangers could also be studied using the methods we have developed. Moreover, research in collaboration with psychotherapists should be carried out to further examine the therapeutic value of using such Virtual Reality scenarios with real patients.

During the experiment we used physiological recording device to measure participants' EDA and ECG responses. The procedure of applying the recording device included applying electrodes on participants' fingers, collar bones, and ribs. The physiological measurements provided objective evidence of participants' anxiety responses during the interaction; however the measurement itself generated problems: first, the wired connections were fragile and sensitive to movements; secondly, due to the way these were applied on the participants, they were highly aware of the equipment, and this might have caused an increase in their feeling of being monitored throughout the experiment. One way to improve this would be to replace the current apparatus with less intrusive and more stable one, something that would be less noticeable to the participants and yet more robust. At the same time, alternative methods of measuring anxiety level should also be investigated. This could be achieved with methods similar to our body movement

analysis presented in Section 4.5.3, but based on higher quality video recordings of participants' body movement obtained through more advanced technology (for instance, cameras that capture movements under poor lighting conditions, stereo cameras, etc.).

7.2 Experiment: Blushing

(a) (b) (c)

Figure 7.2: Experiment: Blushing

Blushing is a facial feature related to shyness and social anxiety, and has not been studied much in character animation. In this experiment we examined how people responded towards blushing in VR, with an experimental design based on existing studies in real life (de Jong 1999; de Jong, Peters et al. 2002; de Jong, Peters et al. 2003). The results show first, that participants tended to withdraw earlier when the avatar was blushing only on the cheek; second, although not consciously noticing the blushing, participants experienced a higher level of co-presence with the whole-face blushing avatar.

In the implementation, only very simple facial animations were included (lip-sync, blinking, head movement). The first thing could be improved in the experiment is the quality of the facial animation of the avatar, which could be modified through a more realistic model for blinking, eye movement, and gaze. Secondly, although participants reported an increased experience in co-presence with the whole-face blushing avatar, more subjective evidence was needed to backup such findings. Due to the design of the experiment we were very careful in not allowing the participant know that his behaviour was observed, so no physiological data were recorded. In future, subjective data should be obtained possibly through a hidden camera, or as

mentioned above, physiological measurement equipment which is less intrusive to the participants.

One of the interesting results was that blushing was perceived at a subconscious level. In human communication, there may be many other aspects which are not perceived consciously. In future, it would be interesting to investigate the level at which these interactions have an impact on relationships between humans, and therefore between avatar and human. Future research could go beyond computer science and psychology to neuroscience, where we could further examine the point at which these interactions interfere with people's consciousness, and where it happens in the brain.

7.3 Experiment: Interview with a Shy Virtual Woman

(a) (b)

Figure 7.3: Experiment: Interview with a Shy Virtual Woman

In this experiment we investigated participants' responses towards the display of shyness in the immersive CAVE-like system. We have animated an avatar with motion captured data which was performed by a professional actress, who acted as if she were very shy (Figure 7.3 (a)) or the opposite (Figure 7.3 (b)). We did not find research about the exact type of interaction (how human response towards someone who behaves as if she is shy in an interview scenario) in real life, however there is some evidence about how people respond towards a shy person (i.e., someone who blushes, see Section 2.4.1) that were taken into consideration in the design of this experiment.

The results of the experiment suggest no difference in the time the participants waited for her to return as between two conditions. However, participants who interacted with the shy avatar gave more positive comments about her, and they were more likely to choose to spend more time with her, which coincides with our expectations. Although in this experiment no difference in participants' behaviour was found, it helped us gain valuable knowledge in the complexity of the interaction between human and avatars, especially when the behaviour of the avatar was very close to real.

In this final experiment, we were interested in finding out how much the difference in avatar's "personality" would influence the participants. Although participants felt more positive towards the personality of the shy avatar, they did not spend more time waiting for her. There were participants who acted exactly like how we predicted: with the "shy" avatar they felt sympathetic and were very patient; and with the "non-shy" avatar they had no patience. As a contrast, there were also participants who acted quite the opposite: although they felt sad about the "shy" avatar, they just wanted to run away from her as soon as possible; and although they dislike the "non-shy" avatar, they patiently waited for her because they were curious to find out more about her. This is yet a reminder of the complexity of human responses: especially when the avatar behaves realistically, the human-avatar interaction is closer to human-human interaction than ever before, which is, of course what we are aiming for.

To be able to understand better how people react towards avatar, future research should focus more on studying the psychology of human-human interaction, and more importantly, seeking evidence at many different levels including psychology and social neuroscience. Another improvement that could be made is adding facial expression and gaze to the avatar. Although participants recognised the shyness expressed through the avatar's body, the lack of facial expressions and gaze might have introduced ambiguity in participants' interpretation of the emotions expressed by the avatar. In future we could add blushing or other simple facial animations related to shyness (increased smiling, for instance) to the avatar, and it would be interesting to see if the combined animation would further improve participants' recognition of shyness on the avatar. Moreover,

our motion captured animation should extend to facial expressions as well as eye movement.

7.4 Contributions and Limitations

This thesis has examined how people interact with Virtual Characters in different virtual encounters, with the focus on social anxiety. In the two experimental studies in the CAVE, we have focused on maintaining a smooth interaction between human participants and the Virtual Character without the necessity of using artificial intelligent techniques. Instead a Wizard of Oz technique was used. Our results have shown that this smooth interaction has contributed in sustaining the feeling of immersion for human participants, and therefore led to potentially high level of emotional engagement, which made it possible to use VR in psychotherapy for social anxiety. In our experimental studies, the experimenter triggers events as the responses of the avatar using the Wizard of Oz techniques. In psychotherapy for social phobia, the therapist could replace the role of the experimenter and select the proper responses as required. Our method uses a simple approach for someone from a non-technical background to learn, and yet provides the flexibility to handle different situations.

Other applications that may benefit from this thesis could be in the areas of film and game industry. In recent years, the audience of animated films and games has shifted from children to a much wider market which involves people from almost all age groups, and therefore has become more and more demanding in terms of emotional engagement. When Virtual Characters are used in such areas, an ultimate goal has been to make the players or audience feel more empathy with the Virtual Character. This thesis has contributed in exploring many different factors that could increase/decrease such an empathic co-presence. For instance, in the experimental studies presented in Chapter 4, the results show that, although represented with low quality appearance and programmed with simple animations by hand, the avatar still triggered very realistic reactions in the participants. In the experimental study on blushing, we found blushing on the whole face increased the co-presence participants felt towards the avatar. In contrast, in our final experiment, the two

different personalities did not change the co-presence participants felt towards the avatar; however, the shy avatar did receive more positive comments.

In the ever growing online society, this thesis could also contribute to applications such as Second Life or any other online applications where there is the need for using Virtual Character as part of the interface as well as representing the users themselves. For example, in future, when someone wants to express embarrassment with their avatar, adding redness on the whole face would be a better idea than adding it just on the cheeks. Or when someone wants their avatar to have a different personality (i.e., shy or confident), information included in this thesis could act as a good reference.

Although this thesis has examined many different aspects of human-avatar interaction, there are limitations in applying the results generated from this research. First of all, this work focused on the behaviour of the avatars. It did not focus on their appearance, nor did it try to provide a systematic solution of the relationship between behaviour and appearance. For instance, we have examined how blushing works with a photo-realistic avatar, where the same results might apply when replaced by an avatar with a different level of realism, such as a cartoon-like avatar. However, there is research suggesting that the mismatch between the levels of realism of the avatar's appearance and behaviour might even reduce users' responses (Vinayagamoorthy, Steed et al. 2005). Another limitation of our thesis is that in the design of all experiments, a real human voice was used for the avatar, which may have by itself had a significant effect in increasing the level of realism. Therefore it is not guaranteed that the same level of responses could be received if this real human voice would be replaced by a computer generated one, thus our findings may not be valid under those circumstances.

7.5 Future Work

This work has focused on a previously under-researched area of emotional interactions between people and Virtual Characters. The findings of this thesis could contribute further the understanding of the human-avatar interaction, particularly the role social anxiety plays in such an interaction. Although tested with specific settings, our findings could be generalised to different types of avatars or scenarios

since standard measurements were used throughout this work. However, there are certain issues one may want to consider when generalising our results.

First, certain results were achieved only because of our particular scenario design. For instance, in our first experiment (Chapter 4) we had a positive female avatar initiating a conversation which became more and more intimate. This made the confident participants more anxious towards the end but the shy ones less anxious, as compared to how they felt in the beginning of the conversation. The shy participants reacted this way maybe because the female avatar was very positive, and there was less effect required from them to maintain the conversation. Therefore participants' responses could be in this way only because there was a positive female avatar interacting with them. If avatar behaves in a different way (i.e., act negatively instead of positively), the responses from the participant could be very different.

Moreover, the setting of our experiments was the interaction between a male participant and a female avatar. Therefore the same results may not apply to different genders or interactions in different social settings other than one-to-one communication. This could be particularly so in our first experiment (Chapter 4) where gender played a significant role: in our case the female avatar "flirted" with the male participants. If the genders were different (i.e. female avatar with female participants), or swapped (i.e. male avatar with female participants), the result could be different. Nevertheless, the findings from our study could still contribute to understanding the outcome of those situations. For instance, one of the recent studies that have referred to our results involved flirting between a male avatar and female participants, and a large part of their methodology could have been derived from our own (Bee, André et al. 2009).

In future, there are two directions of work that should be made. The first is to improve the technology used in implementation and evaluation. As mentioned above, future work should include finding less intrusive equipment in measuring participants' physiological responses. Another technology that needs to be improved is the quality of animation. Future research would look into motion captured data with facial expression, eye movement model, and a way of combining different communicative channels together in character animation.

Secondly, more research in psychology and neuroscience is needed in designing future experiment as well as interpreting the results. As the realism of avatar has increased, the complexity of human-avatar interaction has also increased. In future, designing experiment would involve more intense effort on studying the psychology background of human communication. In the evaluation of future experiments, psychology and neuroscience would be necessary for an in-depth understanding of participants' responses.

Overall in this research we have found that people do tend to respond to avatars in realistic ways, in spite of the relatively low level of their representation in terms of appearance and behaviour. This response to avatars happens at many levels: emotional, behaviour, physiological; and it could interfere with people both consciously and unconsciously. Similarly to various anxieties that may be experienced by people in different social situations, interactions with avatars trigger social anxiety as if they were real. The methodology developed in this thesis would be useful for future research in understanding the role avatars play in VR, and would be of particular value as a reference for developing applications in VR which involves social anxiety.

Appendix A: Published Papers

Pan, X., Gillies M., and Slater, M. (2009) Male Bodily Responses towards a Virtual Woman. In AISB 2009, Edinburgh, UK

Pan, X., Gillies M., and Slater, M. (2008) The Impact of Avatar Blushing on the Duration of Interaction between a Real and Virtual Person. In Presence 2008: The 11th Annual International Workshop on Presence. Pp. 100-106, Padova, Italy.

Pan, X., Gillies M., and Slater, M. (2008) Male Bodily Responses During an Interaction with a Virtual Woman. In IVA 2008, Tokyo, Japan.

Pan, X. & Slater, M. (2008). Bodily Responses towards a Virtual Woman. In RAVE-08, Feb 2008, Barcelona, Spain.

Pan, X. & Slater, M. (2007). A Preliminary Study Of Shy Males Interacting With A Virtual Female. In Presence 2007: The 10th Annual International Workshop on Presence, Pp. 101-108, Barcelona, Spain.

Pan, X., Gillies, M., Sezgin, T. M. & Loscos, C. (2007) Expressing Complex Mental States Through Facial Expressions. In the Second International Conference on Affective Computing and Intelligent Interaction, Lisbon, Portugal

Vinayagamoorthy, V., Gillies, M., Steed, A., Tanguy, E., Pan, X., Loscos, C. & Slater, M. (2006). Building Expression Into Virtual Characters. In Eurographics Conference State of the Art Report, Vienna.

Appendix B: List of Markers for Motion Capture

List of Markers for Motion Capture

The 32 markers used in our motion capture were:

LFWT: left front waist

RFWT: right front waist

LBWT: left back waist

RBWT: right back waist

LKNE: left knee

LANK: left ankle

LHEE: left heel

LTOE: left big toe

LMT5: left little toe

RKNE: right knee

RANK: right ankle

RHEE: right heel

RTOE: right big toe

RMT5: right little toe

STRN: bottom front chest

LFHD: left forehead

RFHD: right forehead

LBHD: left back head

RBHD: right back head

LSHO: left shoulder

LELB: left elbow

LWRB: left outside wrist

LFIN: left finger (end of hand)

RSHO: right shoulder

RELB: right elbow

RWRB: right outside wrist

RFIN: right finger (end of hand)

RWRA: right inside wrist

LWRA: right inside wrist

CLAV: top front chest (near neck)

C7: top back

T10: bottom back

Appendix C: Materials for the Experiment on Real Man Meets Virtual Woman

This appendix contains materials used in the experiment on real man meets virtual woman, as presented in Chapter 4. These include, in order of appearance:

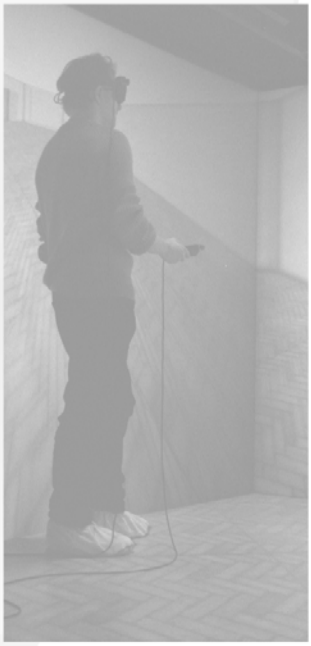
1, Advertisement
2, Pre-SPAI questionnaire
3, Information sheet
4, Consent form
5, Pre-basic questionnaire
6, Script
7, Post-SPAI questionnaire
8, Presence Questionnaire

Advertisement

February 2006

VISIT A VIRTUAL BAR

The study will involve an experience in an immersive virtual reality (VR) system



You are eligible to apply if you:
- Are **MALE**
- Have good vision (eyeglasses are ok)
- Are not subject to epileptic seizures
- Are proficient in English

Payment	£5.00 / hr
Time required	~ 1 hr

Venue

Department of Computer Science,
Malet Place, UCL

Contact us

Tel	020 7679 3672
Email	*experience@cs.ucl.ac.uk*

Quote: "Virtual Bar"

DISCLAIMER: Information collected will be confidential and anonymous.
Results will be reported in aggregate, and any verbal comments made will be presented anonymously

Visit a Virtual Bar
020 7679 3672
experience@cs.ucl.ac.uk

Pre-SPAI questionnaire

PRE-QUESTIONNAIRE

Below is a list of behaviours that may or may not be relevant for you. Based on your personal experience, please indicate how frequently you experience these thoughts and feelings in social situations. A social situation is defined as a gathering of two or more people. For example: a meeting; a lecture; a party; bar or restaurant; conversing with one other person or group of people, etc. FEELING ANXIOUS IS A MEASURE OF HOW TENSE, NERVOUS, OR UNCOMFORTABLE YOU ARE DURING SOCIAL ENCOUNTERS. Please use the scale listed above and circle the number which best reflects how frequently you experience these responses.

Remember that this information is completely confidential

Never	Very Infrequent	Infrequent	Sometimes	Frequent	Very Frequent	Always
1	2	3	4	5	6	7

1. I feel anxious in small gatherings with strangers:

Never 1 2 3 4 5 6 7 Always

2. I feel anxious in small gatherings with authority figures:

Never 1 2 3 4 5 6 7 Always

3. I feel anxious in small gatherings with opposite sex:

Never 1 2 3 4 5 6 7 Always

4. I feel anxious in small gatherings with people in general:

Never 1 2 3 4 5 6 7 Always

5. I feel anxious in a bar or restaurant with strangers:

Never 1 2 3 4 5 6 7 Always

6. I feel anxious in a bar or restaurant with authority figures:

Never 1 2 3 4 5 6 7 Always

7. I feel anxious in a bar or restaurant with opposite sex:

Never 1 2 3 4 5 6 7 Always

8. I feel anxious in a bar or restaurant with people in general:

Never 1 2 3 4 5 6 7 Always

9. I feel anxious and I do not know what to do in a new situation with strangers:

Never 1 2 3 4 5 6 7 Always

10. I feel anxious and I do not know what to do in a new situation with authority figures:

Never 1 2 3 4 5 6 7 Always

11. I feel anxious and I do not know what to do in a new situation with opposite sex:

Never 1 2 3 4 5 6 7 Always

12. I feel anxious and I do not know what to do in a new situation with people in general:

Never 1 2 3 4 5 6 7 Always

13. I feel anxious when discussing intimate feelings with strangers:

Never 1 2 3 4 5 6 7 Always

14. I feel anxious when discussing intimate feelings with authority figures:

Never 1 2 3 4 5 6 7 Always

15. I feel anxious when discussing intimate feelings with opposite sex:

Never 1 2 3 4 5 6 7 Always

16. I feel anxious when discussing intimate feelings with people in general:

Never 1 2 3 4 5 6 7 Always

17. I feel anxious when approaching and/or initiating a conversation with strangers:

Never 1 2 3 4 5 6 7 Always

18. I feel anxious when approaching and/or initiating a conversation with authority figures:

Never 1 2 3 4 5 6 7 Always

19. I feel anxious when approaching and/or initiating a conversation with opposite sex:

Never 1 2 3 4 5 6 7 Always

20. I feel anxious when approaching and/or initiating a conversation with people in general:

Never 1 2 3 4 5 6 7 Always

21. I feel anxious when having to interact for longer than a few minutes with strangers:

Never 1 2 3 4 5 6 7 Always

22. I feel anxious when having to interact for longer than a few minutes with authority figures:

Never 1 2 3 4 5 6 7 Always

23. I feel anxious when having to interact for longer than a few minutes with opposite sex:

Never 1 2 3 4 5 6 7 Always

24. I feel anxious when having to interact for longer than a few minutes with people in general:

Never 1 2 3 4 5 6 7 Always

25. I feel anxious when being criticized or rejected by strangers:

Never 1 2 3 4 5 6 7 Always

26. I feel anxious when being criticized or rejected by authority figures:

Never 1 2 3 4 5 6 7 Always

27. I feel anxious when being criticized or rejected by opposite sex:

Never 1 2 3 4 5 6 7 Always

28. I feel anxious when being criticized or rejected by people in general:

Never 1 2 3 4 5 6 7 Always

29. I attempt to avoid social situations where there are strangers:

Never 1 2 3 4 5 6 7 Always

30. I attempt to avoid social situations where there are authority figures:

Never 1 2 3 4 5 6 7 Always

31. I attempt to avoid social situations where there are opposite sex:

Never 1 2 3 4 5 6 7 Always

32. I attempt to avoid social situations where there are people in general:

Never 1 2 3 4 5 6 7 Always

33. I feel anxious when being approached by strangers:

Never 1 2 3 4 5 6 7 Always

34. I feel anxious when being approached by authority figures:

Never 1 2 3 4 5 6 7 Always

35. I feel anxious when being approached by opposite sex:

Never 1 2 3 4 5 6 7 Always

36. I feel anxious when being approached by people in general:

Never 1 2 3 4 5 6 7 Always

Information Sheet

University College London
Gower Street
London WC1E 6BT UK

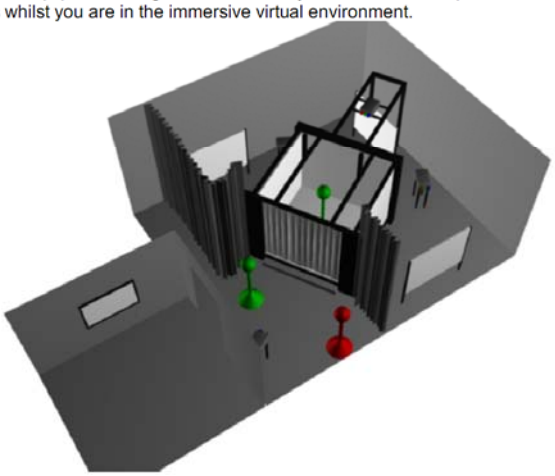
+44 (0)20 7679 3709
+44 (0)20 7387 1397 Fax
M.Slater@cs.ucl.ac.uk
http://www.cs.ucl.ac.uk/staff/M.Slater

Department of Computer Science
Mel Slater
Professor of Virtual Environments

INFORMATION SHEET FOR PARTICIPANTS

Thank you for participating in our study. This is one of a long series of studies into understanding the responses of people within virtual environments. This study has been approved by *University College London's Committee on the Ethics of Non-NHS Human Research*. Please read through this information sheet and feel free to ask any questions. The experimenters will answer any general questions; however the specific aspects regarding this study cannot be discussed with you until the end of the session. The whole study will take about *one hour*.

You will be using the CAVE™-like system called the ReaCTor. See figure below. The ReaCTor is a VR system made up of 3 walls measuring roughly 3m x 3m x 3m. You will wear VR glasses and a tracker. The virtual reality viewing equipment can be worn over eyeglasses. You may be asked to take off your shoes in order to protect the virtual reality equipment. In addition to the tracking equipment used to navigate the system, you will also be fitted with physiological equipment designed to measure your heart rate, respiration and galvanic skin responses whilst you are in the immersive virtual environment.



In this particular study you will be going into a party by yourself and there are a few other people there. Some of them may talk to you, and you can talk with them if you wish. We the experimenters will not be there with you.

PLEASE TURN OVER

Please ask any questions that come to mind. Read and sign the **Consent Form**.

Information that we collect will never be reported in a way that specific individuals can be identified. Information will be reported in a statistical and aggregated manner, and any verbal comments that you make, if written about in subsequent papers, will be presented anonymously.

IMPORTANT

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

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

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

With any type of video equipment there is a possibility that an epileptic episode may be generated. This, for example, has been reported for computer video games.

PROCEDURES

- You will be asked to read, understand and sign a **Consent Form**. If you sign it the study will continue with your participation. **Note that you can withdraw at any time without giving any reasons.**
- You will be asked to complete a number of questions on paper, so that we can try to understand your responses during the study.
- You will be fitted with sensors to measure your heart rate, respiration and galvanic skin responses.
- You may be asked to remove your shoes and switch off mobile phones before using the VR equipment.
- You will have a training period standing in the CAVE for us to collect your physical data as a baseline. You will then go into the environment as mentioned above and stay there for a few minutes during which you will be videotaped.
- After the visit to the environment you will complete a questionnaire about your experience, and a questionnaire which is similar to the one you did before coming.
- Finally there will be a small discussion with the experimenters about your experiences. During this time, you might be audio or video taped.
- **Thank you** for your participation. Please do not discuss this study with others for about **three months**, since the study is continuing.
- Any other questions?

Sylvia Pan
Department of Computer Science
University College London
Gower Street
London WC1E 6BT

+44 (0) 20 7679 3672 *Tel*
+44 (0) 20 7387 1397 *Fax*

s.pan@cs.ucl.ac.uk
http://www.cs.ucl.ac.uk/staff/s.pan

Consent form

Department of Computer Science

Professor Mel Slater
University College London
Gower Street
London WC1E 6BT UK

+44 (0)20 7679 3709
+44 (0)20 7387 1397 Fax
m.slater@cs.ucl.ac.uk

Virtual Reality Study Consent Form

Please read and answer the following questions carefully:

Have you read the information sheet about this study?	YES/NO
Have you had an opportunity to ask questions about the procedure?	YES/NO
Have you received satisfactory answers to all your questions?	YES/NO
Have you received enough information about this study?	YES/NO
Do you understand that you are free to withdraw from this study at any time and without giving a reason for withdrawing?	YES/NO
Do you understand and accept the risks associated with the use of virtual reality equipment?	YES/NO
Do you agree to take part in this study?	YES/NO

We would like to audiotape your interview. This tape will be used for data analysis purposes only and will be kept entirely confidential

Do you agree to be audiotaped? YES/NO

Please check:

I certify that I do not have epilepsy ☐

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

Signed……..……Date……

Name in block letters ……..……

Pre-basic questionnaire

Your Given ID number	
Your Age	
Your Gender	☐ Male ☐ Female
How fluent is your English?	Basic ☐ Proficient ☐ Fluent ☐
Occupational status	Undergraduate Student ☐ Masters Student ☐ PhD Student ☐ Research Assistant/Fellow ☐ Staff - systems, technical ☐ Faculty ☐ Administrative Staff ☐ Other ☐
Are you taking any medication?	☐ Yes ☐ No *If yes, please specify*
Did you consume more than 2 units of alcohol within the last 6 hours? *(2 units of alcohol = 1 pint of beer or 2 glasses of wine)*	☐ Yes ☐ No
Please state your level of computer literacy on a scale of (1...7) (novice) 1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ (expert)	
Please rate your level of experience with computer *programming*: (novice) 1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ (expert)	
Have you ever experienced 'virtual reality' before? (no experience) 1☐ 2☐ 3☐ 4☐ 5☐ 6☐ 7☐ (extensive experience)	
How many times did you play video games (at home, work, school, or arcades) in the last year?	Never ☐ 1 - 5 ☐ 6 - 10 ☐ 11 - 15 ☐ 16 - 20 ☐ 21 - 25 ☐ > 25 ☐
How many *hours per week* do you spend playing video games?	0 ☐ < 1 ☐ 1 - 3 ☐ 3 - 5 ☐ 5 - 7 ☐ 7 - 9 ☐ > 9 ☐

Script

444 Gaze
555 Proxemics 1 (Social distance)
1 Hi, It looks like we are the only people alone here, right?
2 My name is Christina.
3 What's your name?
4 It's very nice to meet you.
5 So, what are you doing for a living?
6 Very interesting, tell me.
7 Oh, what's your subject?
9 enhen
10 I'm an air hostess, I just arrived in London yesterday. Where do you live?
11 It's that a nice area?
12 I don't know London very well, but actually, I am thinking about moving here, what do you think?
13 But I heard it rains all the time here, is that true?
131 En, I heard it rains all the time here, is that true?
14 Well, the weather is not that important to me. Have you lived here long?
141 Have you lived here long?
15 Do you like it here?
16 I've noticed that people dressed very well around here. By the way, that shirt looks great on you. How much was it?
17 Ah, I really want to find a pair of trousers, something like these(Looking down) for my brother. Where did you get these?
18 So, do you know anyone here?
19 I feel a bit shy about talking with other people, do you mind if I talk with you for a bit longer?
666 Proxemics 2 (Intimate distance)
20 If you don't mind me saying, I think you look very nice.
21 I was wondering actually, are you single, or involved with someone at this time?
220 Actually, it is the same with me. (Positive)
221 Actually, it is the same with me. (Negative)
23 Anyway, what are you doing after this party?
240 Alright, I see. (Positive)
241 Alright, I see. (Negative)
25 Maybe we should meet up.
26 I just need to go out for a minute, shall we meet by the entrance of this building later?
777 See you later! -- Experiment ends

Backups:
31 I work with Air France.
32 Now, I cannot tell you all my secrets.

36 Ha ha ha.
41 Yes?
42 Yes.

Post-SPAI

Post Questionnaire: SPAI

This questionnaire is composed of 35 statements regarding your feelings about the experience that you have just had in the virtual party. Please answer each of the questions below with the following scale.

1.NEVER

2.VERY INFREQUENTLY

3.INFREQUENTLY

4.SOMETIMES

5.FREQUENTLY

6.VERY FREQUENTLY

7.ALWAYS

Below is a list of behaviours that may or may not have been relevant for you. Based on your personal experience, please indicate how frequently you experienced these thoughts and feelings in the experience that you have just had.

1. I felt anxious when entering the party and noticing that there were small groups of people.....

1 2 3 4 5 6 7

2. I felt anxious when I thought I might have become the centre of attention....

1 2 3 4 5 6 7

3. I felt anxious because I thought I was expected to engage in some activity.....

1 2 3 4 5 6 7

4. I felt so anxious that I wanted to avoid being there at all....

1 2 3 4 5 6 7

5. I felt so anxious that I wanted to leave.....

1 2 3 4 5 6 7

6. I felt anxious because there were...

Strangers.....

1 2 3 4 5 6 7

7. I felt anxious because there were...

Members of the opposite sex.....

1 2 3 4 5 6 7

8. I felt anxious because there were...

The people there in general.....

1 2 3 4 5 6 7

9. I felt anxious and did not know what to do in this new situation with.....

Strangers.....

1 2 3 4 5 6 7

10. I felt anxious and did not know what to do in this new situation with.....

Members of the opposite sex.....

1 2 3 4 5 6 7

11. I felt anxious and did not know what to do in this new situation with.....

The people there in general.....

1 2 3 4 5 6 7

12. I felt anxious about approaching or initiating a conversation with.....

Strangers.....

1 2 3 4 5 6 7

13. I felt anxious about approaching or initiating a conversation with.....

Members of the opposite sex.....

1 2 3 4 5 6 7

14. I felt anxious about approaching or initiating a conversation with.....

The people there in general.....

1 2 3 4 5 6 7

15. I felt anxious because I had to interact for a while with....

Strangers.....

1 2 3 4 5 6 7

16. I felt anxious because I had to interact for a while with....

Members of the opposite sex.....

1 2 3 4 5 6 7

17. I felt anxious because I had to interact for a while with....

The people there in general.....

1 2 3 4 5 6 7

18. I wanted to leave the party because there were...

Strangers.....

1 2 3 4 5 6 7

19. I wanted to leave the party because there were...

Members of the opposite sex.....

1 2 3 4 5 6 7

20. I wanted to leave the party because there were...

The people there in general.....

1 2 3 4 5 6 7

21. While I was in the party I was thinking about the things that might be going wrong in that situation. The types of thoughts I experienced were:

Am I dressed properly?

1 2 3 4 5 6 7

22. While I was in the party I was thinking about the things that might be going wrong in that situation. The types of thoughts I experienced were:

Will I make a mistake and look foolish?

1 2 3 4 5 6 7

23. While I was in the party I was thinking about the things that might be going wrong in that situation. The types of thoughts I experienced were:

What if no one speaks to me?

1 2 3 4 5 6 7

24. While I was in the party I was thinking about the things that might be going wrong in that situation. The types of thoughts I experienced were:

If there is silence will I think of something to say?

1 2 3 4 5 6 7

25. My voice left me in that situation....

1 2 3 4 5 6 7

26. I was not going to speak until someone spoke to me.....

1 2 3 4 5 6 7

27. I experienced troublesome thoughts. For example:

I wished I could leave and avoid the whole situation...

1 2 3 4 5 6 7

28. I experienced troublesome thoughts. For example:

If I messed up again I would lose my confidence...

1 2 3 4 5 6 7

29. I experienced troublesome thoughts. For example:

What kind of impression am I making?

1 2 3 4 5 6 7

30. I experienced troublesome thoughts. For example:

Whatever I say it will probably sound stupid....

1 2 3 4 5 6 7

31. I experienced the following...

Sweating....

1 2 3 4 5 6 7

32. I experienced the following...

Blushing....

1 2 3 4 5 6 7

33. I experienced the following...

Shaking....

1 2 3 4 5 6 7

34. I experienced the following...

Frequent urge to urinate....

1 2 3 4 5 6 7

35. I experienced the following...

Heart palpitations....

1 2 3 4 5 6 7

Presence- Questionnaire
Virtual Reality Study
QUESTIONNAIRE

Please make sure that you answer each question. If you have any queries ask the experimenters who will be nearby.

Please note that in this questionnaire 'VR *laboratory*' refers to the physical space in which the study is taking place, and 'party' refers to the room that contained yourself and the virtual people

1 How much were you aware of background sounds in the VR laboratory in which this experience was actually taking place. Rate this on the following scale from 1 to 7 (where for example 1 means that you were not at all aware of the background sounds).

During the experience I was aware of background sounds from the laboratory...

not at all 1 2 3 4 5 6 7 very much so

2 How dizzy, sick or nauseous did you feel resulting from the experience, if at all?

I felt sick or dizzy or nauseous during or as a result of the experience...

not at all 1 2 3 4 5 6 7 very much so

3 Please rate *your sense of being in the party*, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a place.*

I had a sense of being there in the party...

at no time 1 2 3 4 5 6 7 almost all the time

4 To what extent were there times during the experience when the party was the reality for you?

There were times during the experience when party was the reality for me...

at no time 1 2 3 4 5 6 7 almost all the time

5 When you think back about your experience, do you think of the party more as *images that you saw*, or more as *somewhere that you visited*?

The party seemed to be more like...

images that I saw 1 2 3 4 5 6 7 somewhere I visited

6 During the time of the experience, which was strongest on the whole, your sense of being in the party, or of being in the real world of the laboratory?

I had a stronger sense of...

being in the lab 1 2 3 4 5 6 7 being in the party

7 How much did you enjoy the party?

I enjoyed the party ……

not at all 1 2 3 4 5 6 7 very much

8 During the time of the experience were you more aware of being in a laboratory or being at the party?

During the experience I was aware more of ...

Being in the lab 1 2 3 4 5 6 7 Being at the party

9 During the course of the experience, how much were you aware of the experimenters?

During the course of the experience I was aware of the experimenters …

not at all 1 2 3 4 5 6 7 very much

10 How much was your overall behaviour like being in a party?

In my overall behaviour I responded as if I were at the party …

not at all 1 2 3 4 5 6 7 very much

11 How often did you find yourself *automatically* behaving within the party as if it were a real place?

I responded as if it were a real place…

never 1 2 3 4 5 6 7 almost all the time

12 How much was what you said like what you would have said in a real situation?

I spoke as if the situation were a real one…

never 1 2 3 4 5 6 7 almost all the time

13 How much was your emotional response in the party the same as if it had been real?

My emotional response in the party was the same as if it had been real …

never 1 2 3 4 5 6 7 almost all the time

14 How much were the thoughts you had within the party the same as if it had been a real situation?

My thoughts with in the party were the same as if it had been real …

never 1 2 3 4 5 6 7 almost all the time

15 How much were you thinking things like 'I know this isn't real' but then surprisingly finding yourself behaving as if it was real?

In spite of my knowledge that the situation wasn't real I found myself behaving as if it were real…

never 1 2 3 4 5 6 7 almost all the time

16 To what extent were your physical responses within the party (e.g., heart rate, blushing, sweating, etc.) the same as if it had been a real situation? (In this case if in such a real situation you would have had no or few such physical responses and also within the party you had no or few physical responses, then your answer should be closer to 7 than to 1).

My physical responses within the party were the same as if it had been real …

never 1 2 3 4 5 6 7 almost all the time

There was a virtual woman in the experience that you have just had who spoke to you, and she is referred to here as the 'woman'

17 How much did you behave as if the woman were real?

I behaved as if she as if she were real…

not at all 1 2 3 4 5 6 7 very much

18 How much was what you said to her like what you would have said to a real woman in a similar situation?

The things I said to her were similar to what I would have said had she been real…

not at all very much

19 How much did you *find yourself automatically* behaving as if the woman were real?

I found myself automatically behaving as if she were real …

not at all very much

20 How much was your overall emotional response to the woman as if she were real?

My overall emotional response to her was as if she were real …

not at all 1 2 3 4 5 6 7 very much

21 How much were the types of things you were thinking while talking with her similar to a real situation?

My thoughts when talking with her were as if she were real …

not at all 1 2 3 4 5 6 7 very much

22 How much did you have physical responses (such as change in heart rate, blushing, sweating, etc.) to the woman as if she were real?

My physical responses to her were as if she were real…

not at all 1 2 3 4 5 6 7 very much

23 How much were you thinking things like 'I know this person isn't real' but then surprisingly finding yourself behaving as if she was real?

In spite of my knowledge that she wasn't real I found myself behaving as if she were real…

never almost 1 2 3 4 5 6 7 all the time

24 How much were you aware of the other people in the party looking at you?

I was aware of the other people taking notice of me...

not at all very much so

25 To what extent did it disturb you, if at all, if the other people in the party looked at you?

If I noticed that the others at the party looked at me, it…

Did not disturb me at all it disturbed me very much

26 To what extent, if at all, did you become anxious when the woman approached you and started talking with you?

When the woman approached me and started talking to me I become anxious…

not at all 1 2 3 4 5 6 7 very much so

27 To what extent, if at all, did your feelings about the conversation with the woman change over time. Please answer YES or NO to each of the following:

I became more anxious over time. YES/NO

I became less anxious over time. YES/NO

I became more confident over time. YES/NO

I became less confident over time. YES/NO

I became more relaxed over time. YES/NO

I became less relaxed over time. YES/NO

Please enter your comments. Things you could consider are:

- Aspects of the experience that made you respond as if it were real.
- Aspects of the experience that led you to make responses that would have been unrealistic if the situation depicted had been occurring in reality.
- Aspects of the situation that suddenly disturbed your experience of being in the party.
- Aspects of the experience that helped or hindered you achieving your task.
- Aspects of your feelings towards the experience
- …

Please write your answer in the space below:

Appendix D: Materials for the Experiment on Blushing

This appendix contains materials used in the experiment on real blushing, as presented in Chapter 5. These include, in order of appearance:
1, Advertisement
2, Information sheet
3, Consent form
4, Instruction
5, Post-experiment questionnaire
6, Extra questions on blushing

The pre-basic questionnaire was also used in this experiment, which is the same as shown in Appendix C. Apart from the questionnaires on the list, two standard questionnaire were also included (NEO and POMS).

Advertisement

Volunteers Needed for Virtual Reality Study

Virtual Agent Experiment - Earn £5.00

The experiment will take approximately **30 minutes**, and will be performed in the **Department of Computer Science, Malet Place, UCL** over the next few weeks.

You are eligible to apply if you are **Native in English**.

If you would like to participate, please contact **Sylvia** by sending an email to experience@cs.ucl.ac.uk and quote keyword "**Virtual Agent**", or by calling 020 7679 3672.

Information Sheet for Participants

Thank you for participating in our study. This study has been approved by *University College London's Committee on the Ethics of Non-NHS Human Research*. Please read through this information sheet and feel free to ask any questions. The experimenters will answer any general questions; however the specific aspects regarding this study cannot be discussed with you until the end of the session. The whole study will take about *20 - 30 minutes*.

In this particular study you will be watching a presentation about Beijing 2008 Olympic Games.

Please ask any questions that come to mind. Read and sign the **Consent Form**.

Information that we collect will never be reported in a way that specific individuals can be identified. Information will be reported in a statistical and aggregated manner, and any verbal comments that you make, if written about in subsequent papers, will be presented anonymously.

Procedures
You will be asked to read, understand and sign a **Consent Form**. If you sign it the study will continue with your participation. **Note that you can withdraw at any time without giving any reasons.**
You will be asked to complete a number of questions on paper, so that we can try to understand your responses during the study.
You will be then be introduced into the lab and watch a presentation about Beijing 2008 Olympic Games
After the presentation you will complete a questionnaire about your experience.
Finally there will be a small discussion with the experimenters about your experiences. During this time, you might be audio taped.
Thank you for your participation. Please do not discuss this study with others for about **three months**, since the study is continuing.
Any other questions?

Please note that you may (or may not) find the situation that is depicted within the presentation stressful. If at any time you do not wish to continue participating in the experiment remember that you are free to withdraw without being required to give reasons.

In case you have any enquiries regarding this study in the future, please contact:
Mel Slater, Department of Computer Science, UCL. m.slater@cs.ucl.ac.uk
Telephone: 020 7679 3709

Consent Form

UCL Ethics Project ID Number: 0172/003

Investigators: Mel Slater, Xueni Pan

Virtual Reality Study Consent Form
Please read and answer the following questions carefully:
Have you read the information sheet about this study?
YES/NO
Have you had an opportunity to ask questions about the procedure?
YES/NO
Have you received satisfactory answers to all your questions?
YES/NO
Have you received enough information about this study?
YES/NO
Do you understand that you are free to withdraw from this study
at any time and without giving a reason for withdrawing? YES/NO
Do you agree to take part in this study?
YES/NO

We would like to audiotape your interview. This tape will be used for data analysis purposes only and will be kept entirely confidential

Do you agree to be audio-taped?
YES/NO

Signed……Date……

Name in block letters ……

Instruction:

1,Your task is to evaluate the software, which is a web application designed to give an interactive presentation.

2, The experiment is testing your independent interaction with the software. As such the experimenter cannot give you any help or advice. So please do not ask any question once the presentation starts.

3, The whole presentation lasts about 4 to 5 minutes. You may stop at any time by pressing the stop button.

4, You should then start filling in the three questionnaires given. Please complete questionnaires in order.

5, Please do leave some comments on the third questionnaire.

6, After finishing the three questionnaires, you may leave or ask any questions to the experimenter.

Post-questionnaire

In this questionnaire, the 'she' refers to the virtual agent that appeared in the presentation. The 'incident' refers to the 'database loading problem'.

1, What are your feeling about her? Is she:

Unreliable	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Reliable**
Dishonest	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Honest**
Antisocial	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Social**
Unfriendly	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Friendly**
Unsympathetic	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Sympathetic**
Unlikeable	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Likeable**

2, How do you assess the seriousness of the incident?

Not at all 0 1 2 3 4 5 6 7 Very serious

3, How much do you consider her as responsible for the incident?

Not at all 0 1 2 3 4 5 6 7 Highly responsible

4, How much do you think she felt sorry about the incident?

Not at all 0 1 2 3 4 5 6 7 She felt very sorry

5, How embarrassed do you think she was about the incident?

Not at all 0 1 2 3 4 5 6 7 She was very embarrassed

6, Imagine, if you were the administrator of the 2008 Beijing Olympic Games, will you offer her a job as a guide?

Yes/No

7, How long do you think you spent on the whole presentation? (Please fill in the blank)

I think the presentation took about ____ minutes and____ seconds.

8, How much did you find yourself responding to her as if she were a real person?

(a) concerning your thoughts

Not at all 0 1 2 3 4 5 6 7 Very much

(b) concerning your feelings and emotions

Not at all 0 1 2 3 4 5 6 7 Very much

(c) concerning your physical responses

Not at all 0 1 2 3 4 5 6 7 Very much

Extra questions on blushing

ID: **Date:**

1, How much do you think she blushes?

Not at all 0 1 2 3 4 5 6 7 Very much

2, Do you blush a lot in everyday life?

Not at all 0 1 2 3 4 5 6 7 Very much

3, When other people blush, do you usually notice it?

Never 0 1 2 3 4 5 6 7 Always

4, Did you blush just then?

Not at all 0 1 2 3 4 5 6 7 Very much

5, Any comments?

Appendix E: Materials for the Experiment on Interview with a Shy Avata

This appendix contains materials used in the experiment on Interview with a shy avatar, as presented in Chapter 4. These include, in order of appearance:

1, Advertisement used for recruitment

2, Information Sheet

3, Consent Form

4, SAD questionnaire

5, Script

6, Questionnaire given during the experiment

7, Presence Questionnaire given after the experiment

Another 2 questionnaire were also used in the experiment, one was the standard NEO questionnaire. The other one was the pre-basic questionnaire which was as the same as in the experiment on real man meets virtual woman (appendix C).

Advertisement

Virtual Interview

You are eligible to apply if you:
- Have good vision (eyeglasses are ok)
- Are not subject to epileptic seizures
- Are **native English speaker**

Time required: 1hr
Payment: £10.00

Venue:
Department of Computer Science, Malet Place, UCL

Contact us:
Please contact us by emailing to: experience@cs.ucl.ac.uk
With the subject: virtual interview

DISCLAIMER: Information collected will be confidential and anonymous. Results will be reported in aggregate, and any verbal comments make will be presented anonymously

Information Sheet for Participants

Thank you for participating in our study. This study has been approved by *University College London's Committee on the Ethics of Non-NHS Human Research*. Please read through this information sheet and feel free to ask any questions. The experimenters will answer any general questions; however the specific aspects regarding this study cannot be discussed with you until the end of the session. The whole study will take about *one hour*.

In this particular study you will be giving an interview to a person in virtual reality (the interviewee).

Please ask any questions that come to mind. Read and sign the **Consent Form**.

Information that we collect will never be reported in a way that specific individuals can be identified. Information will be reported in a statistical and aggregated manner, and any verbal comments that you make, if written about in subsequent papers, will be presented anonymously.

Procedures:

You will be asked to read, understand and sign a **Consent Form**. If you sign it the study will continue with your participation. **Note that you can withdraw at any time without giving any reasons.**

You will be asked to complete a number of questions on a computer display, so that we can try to understand your responses during the study.

You will be then be introduced into the lab and give an interview to the interviewee, with step by step instructions displayed on a laptop in front of you.

The whole session will be videotaped for our records.

After the interview you will complete a questionnaire about your experience.

Finally there will be a short audiotaped discussion with the experimenters about your experiences.

Thank you for your participation. Please do not discuss this study with others for about **three months**, since the study is continuing.

Any other questions?

Please note that you may (or may not) find the situation that is depicted within the presentation stressful. If at any time you do not wish to continue participating in the experiment remember that you are free to withdraw without being required to give reasons.

In case you have any enquiries regarding this study in the future, please contact:

Mel Slater, Department of Computer Science, UCL. m.slater@cs.ucl.ac.uk

Telephone: 020 7679 3709

Content Form

UCL Ethics Project ID Number: 1336/001

Investigators: Mel Slater, Xueni Pan

Virtual Reality Study Consent Form

Please read and answer the following questions carefully:

Have you read the information sheet about this study?

YES/NO

Have you had an opportunity to ask questions about the procedure?

YES/NO

Have you received satisfactory answers to all your questions?

YES/NO

Have you received enough information about this study? YES/NO

Do you understand that you are free to withdraw from this study

at any time and without giving a reason for withdrawing? YES/NO

Do you agree to take part in this study?

YES/NO

Do you agree that we can videotape you during the experiment and audiotape your interview? These tapes will be used for data analysis purposes only and will be kept entirely confidential.

YES/NO

Signed……..……Date……

Name in block letters ……..……

SAD Questionnaire

This questionnaire is composed of 27 statements regarding your feelings in social gatherings. Choose "Agree" if you consider the statement is true of your feelings most of the time. Choose "Disagree" if you consider the statement is rarely true for you. Remember that this information is completely *confidential.*

1. You feel relaxed even in unfamiliar social situations.	Agree	Disagree
2. You try to avoid situations which force you to be very sociable.	Agree	Disagree
3. It's easy for you to relax when you are with strangers.	Agree	Disagree
4. When your superiors want to talk to you, you talk willingly.	Agree	Disagree
5. You often find social settings upsetting.	Agree	Disagree
6. You usually feel calm and comfortable in social situations.	Agree	Disagree
7. You are usually at ease when talking to someone of the opposite sex.	Agree	Disagree
8. You try to avoid talking to people unless you know them well.	Agree	Disagree
9. If the chance comes to meet new people, you often take it.	Agree	Disagree
10. You often feel nervous or tense in casual get-togethers in which both sexes are present.	Agree	Disagree
11. You are usually nervous with people unless you know them well	Agree	Disagree
12. You usually feel relaxed when you are with a group of people.	Agree	Disagree
13. You often want to get away from people.	Agree	Disagree
14. You usually feel uncomfortable when you are in a group of people you don't know.	Agree	Disagree
15. You usually feel relaxed when you meet someone for the first time.	Agree	Disagree
16. Being introduced to people makes you tense and nervous.	Agree	Disagree
17. Even though a room is full of strangers you may enter it anyway.	Agree	Disagree
18. You would avoid walking up to and joining a large group of people.	Agree	Disagree
19. You sometimes take the responsibility for introducing people to each other.	Agree	Disagree
20. You often feel on edge when you talk to a group of people.	Agree	Disagree
21. You tend to withdraw from people.	Agree	Disagree
22. You don't mind talking to people at parties or social gatherings.	Agree	Disagree
23. You are seldom at ease in a large group of people.	Agree	Disagree
24. You often think up excuses in order to avoid social engagements.	Agree	Disagree
25. You try to avoid formal social occasions.	Agree	Disagree
26. You usually go to whatever social engagements you have.	Agree	Disagree
27. You find it easy to relax with other people.	Agree	Disagree

Script of the Experiment: Virtual Interview

The script of the avatar is highlighted in bold. The expected responses from the participant are also given as a reference.

Off Scene Voice (before Jenny shows up, David: the authority figure):

David: Ok, your turn now. Are you ready?
Jenny: Do I really, have to go through this?
David: I'm afraid yes, as we have agreed.
Jenny: But I'm not…
David: Oh come on, she/he is here already, waiting for you. Go in and sit there, quick!
Jenny: o…k… (coughing, steps)

Part 1: introducing (All step by step instructions are displayed on a laptop in front of the participant)

(Jenny walks in to the scenario and sits down on the chair in front of the participant.)
intro1: Hi.
Hi, what's your name?
intro2: I'm Jenny, nice to meet you.
Nice to meet you too.
intro3: Shall we start?
(Read from the laptop)The reason for seeing you, XXXX, is that I need to go through a questionnaire with you, to assess your feelings in interactions with people. This is part of a long series of studies that we have been doing on social relationships, and your answers will be very helpful for us.
intro4: OK
(Read from the laptop) There will be 27 questions to answer, and the total time will be about 5 minutes. Here is an example: I would make a statement such as: "You feel relaxed even in unfamiliar social situations" and then you should respond "I agree" or "I Do not agree" – it is that simple.
intro5: I see.
(Read from the laptop) We just go through these questions one by one until we have finished. I'm sorry I am reading out these instructions XXXX but it is important that we say exactly the same things to everyone.
intro6: It's ok.
(Read from the laptop) Do you realise XXXX that the answers you give will be completely confidential, and that we will only refer to them in statistical form?
intro7: So I've been told. Why do you keep using my name, it is like you're trying to sell me something.
Let's do a rehearsal: you feel relaxed even in unfamiliar social situations. Agree or disagree?
intro8: Sorry? Could you say it again?
Participant repeats the question.

intro9: This right now is an unfamiliar social situation isn't it?
Yes, please answer the question.
intro10: I'd say I disagree, I don't feel relaxed now, for example.
OK, are you ready to start?
intro11: I suppose so.

Part 2: Questions (All questions are given on a laptop in front of the participant)

q1	You feel relaxed even in unfamiliar social situations. **J: As I just said, no, I disagree**
q2	You try to avoid situations which force you to be very sociable. **J: (Coughing) Yes, I agree**
q3	It's easy for you to relax when you are with strangers. **J: No, I disagree.**
q4	When my superiors want to talk to you, you talk willingly. **J: eh…I disagree.**
q5	You often find social settings upsetting. **J: I wouldn't say 'often' so I disagree.**
q6	You usually feel calm and comfortable in social situations. **J: No, not 'usually' I disagree.**
q7	You are usually at ease when talking to someone of the opposite sex. **q71: Say it again? (blush)** **q72: Oh, do, do I have to answer this question?** **q73: Eh, I disagree.**
q8	You try to avoid talking to people unless you know them well. **J: No, I disagree.**
q9	If the chance comes to meet new people, you often take it. **J: Well, it depends on who they are, but I agree I suppose. (smile)**
q10	You often feel nervous or tense in casual get-togethers in which both sexes are present. **J: Yes I agree I usually feel nervous if I don't know who will be there.**
q11	You are usually nervous with people unless you know them well **J: I agree.**

q12	You usually feel relaxed when you are with a group of people. **J: I disagree.**
q13	You often want to get away from people. **J: I do. I agree. This is a bit embarrassing, isn't it?** **(J: I do. I agree. These questions are very embarrassing for me)**
q14	You usually feel uncomfortable when you are in a group of people you don't know. **J: I feel uncomfortable now, so of course I agree.**
q15	You usually feel relaxed when you meet someone for the first time. **J: Never (smile). I disagree.**
q16	Being introduced to people makes you tense and nervous. **J: Yes. I agree.**
q17	Even though a room is full of strangers you may enter it anyway. **J: En, I think so. I agree.**
q18	You would avoid walking up to and joining a large group of people. **J: Yes. I agree. (blush)**
q19	You sometimes take the responsibility for introducing people to each other. **q191: Sorry, what?** **q192: Yes, I agree, anyway if I know them. (more relaxed)**
q20	You often feel on edge when you talk to a group of people. **J: Yes, I agree.**
q21	You tend to withdraw from people. **J: (blushing). Yes, I agree.**
q22	You don't mind talking to people at parties or social gatherings. **J: en, (pause) I disagree, I do mind!**
q23	You are seldom at ease in a large group of people. **J: Yes, I agree.**
q24	You often think up excuses in order to avoid social engagements. **J: eh. En, well, en, yes, I, I agree.**

q25	You try to avoid formal social occasions. **J: Yes, I agree.**
q26	You usually go to whatever social engagements you have. **J: No, I disagree.**
q27	You find it easy to relax with other people. **J: hehe (giggling), no, I disagree.**

Part 3: ending

end1: Have we finished?
Yes, I think so.
end2: Great. Thanks.
Do you have any comments?
end3: I think you did very well. Actually, do you mind if I ask you a favour.
Sure.
end4: They've told me they've set up another questionnaire on the laptop, right in front of you. Can you see it?
Where is it?
end41: It's just on the laptop, have you tried clicking the "next" button?
Ah, I can see it now.
end5: It's a questionnaire about me. Do you mind filling it now please? It doesn't take long.
OK.
end6: If you don't mind, please do it now. And they've also asked me to go through your answers with you when you've done it.
What?
end61: They've also asked me to go through your answers with you when you finish.
OK.
end7: So after you have finished just let me know. Look I have to go out for a minute to get this. When you finish the questionnaire just ring that bell [pointing] on the desk, just to the left of the laptop, and I will come back to see you before you go.
OK.
(In case the participant doesn't understand)
end71: There is a bell on the left of the laptop. When you finish the questionnaire just ring that bell, and I will come back to see you before you go.
Fine, but can I ask…
end8: Look I have to go now; we can talk about it when I'm back.
(Jenny stands up and quickly walks away.)

Backups:
1, Keke (coughing)

2, Never mind, let's just carry on.
3, I don't know.
4, I don't think so.
5, Let's just carry on.
6, What's the next question?
7, What's next?
8, It's alright, don't worry.
9, Fine, thanks.

Questionnaire given during the experiment

Those are the questions given on a laptop during the experiment:

1, I liked the interviewee.

Agree Disagree

2, I would like to spend more time with the interviewee.

Agree Disagree

3, I feel the interviewee is reliable.

Agree Disagree

4, I feel the interviewee is honest.

Agree Disagree

5, I feel the interviewee is sociable.

Agree Disagree

6, I feel the interviewee is friendly.

Agree Disagree

7, I feel the interviewee is sympathetic.

Agree Disagree

8, I feel the interviewee is trustworthy.

Agree Disagree

Presence Questionnaire
Virtual Reality Study
QUESTIONNAIRE

Please make sure that you answer each question. If you have any queries ask the experimenters who will be nearby.

Please note that in this questionnaire 'VR *laboratory*' refers to the physical space in which the study is taking place, and 'interview' refers to the room that contained yourself and the virtual people

1 How much were you aware of background sounds in the VR laboratory in which this experience was actually taking place. Rate this on the following scale from 1 to 7 (where for example 1 means that you were not at all aware of the background sounds).

During the experience I was aware of background sounds from the laboratory...

not at all 1 2 3 4 5 6 7 very much so

2 How dizzy, sick or nauseous did you feel resulting from the experience, if at all?

I felt sick or dizzy or nauseous during or as a result of the experience...

not at all 1 2 3 4 5 6 7 very much so

3 Please rate *your sense of being in the interview*, on the following scale from 1 to 7, where 7 represents your *normal experience of being in a place.*

I had a sense of being there in the interview...

at no time 1 2 3 4 5 6 7 almost all the time

4 To what extent were there times during the experience when the interview was the reality for you?

There were times during the experience when the interview was the reality for me...

at no time 1 2 3 4 5 6 7 almost all the time

5 When you think back about your experience, do you think of the interview more as *images that you saw*, or more as *somewhere that you visited*?

The interview seemed to be more like...

images that I saw 1 2 3 4 5 6 7 somewhere I visited

6 During the time of the experience, which was strongest on the whole, your sense of being in the interview, or of being in the real world of the laboratory?

I had a stronger sense of...

being in the interview 1 2 3 4 5 6 7 being in the lab

7 Overall, how well do you think that you achieved the task?

I achieved the task ……

not at all 1 2 3 4 5 6 7 fully

8 During the time of the experience, did you often think to yourself that you were just sitting in a laboratory or did the interview overwhelm you?

During the experience I was thinking that I was really in the VR laboratory...

most of the time 1 2 3 4 5 6 7 rarely

9 During the course of the experience, how much were you aware of the experimenters?

During the course of the experience I was aware of the experimenters …

not at all 1 2 3 4 5 6 7 very much

10 How much did you behave within the interview as if the situation were real?

I responded as if the situation were real …

not at all 1 2 3 4 5 6 7 very much

11 How much was your emotional response in the interview the same as if it had been real?

My emotional response in the interview was the same as if it had been real …

never 1 2 3 4 5 6 7 almost all the time

12 How much were the thoughts you had within the interview the same as if it had been a real situation?

My thoughts with in the interview were the same as if it had been real …

never 1 2 3 4 5 6 7 almost all the time

13 How much were you thinking things like ‘I know this isn’t real’ but then surprisingly finding yourself behaving as if it was real?

In spite of my knowledge that the situation wasn’t real I found myself behaving as if it were real…

never 1 2 3 4 5 6 7 almost all the time

14 To what extent were your physical responses within the interview (e.g., heart rate, blushing, sweating, etc.) the same as if it had been a real situation? (In this case if in such a real situation you would have had no or few such physical responses and also within the interview you had no or few physical responses, then your answer should be closer to 7 than to 1).

My physical responses within the interview were the same as if it had been real …

never 1 2 3 4 5 6 7 almost all the time

There was a virtual character in the experience that you have just interviewed, who is referred to here as the 'interviewee'

15 How much did you behave as if the interviewee were real?

I behaved as if he/she were real…

not at all 1 2 3 4 5 6 7 very much

16 Overall how much did you treat the interview as if it were real?

I treated the interview as if it were real…

not at all 1 2 3 4 5 6 7 very much

17 How much was your emotional response to the interviewee as if he/she were real?

My emotional response to him/her was as if he/she were real …

not at all 1 2 3 4 5 6 7 very much

18 How much were your thoughts in relation to the interviewee as if he/she were real?

My thoughts in relation to him/her were as if he/she were real …

not at all 1 2 3 4 5 6 7 very much

19 How much did you have physical responses (such as change in heart rate, blushing, sweating, etc.) to the interviewee as if he/she were real?

My physical responses to him/her were as if he/she were real…

not at all 1 2 3 4 5 6 7 very much

20 How much were you thinking things like 'I know this person isn't real' but then

surprisingly finding yourself behaving as if he/she was real?

In spite of my knowledge that he/she wasn't real I found myself behaving as if he/she were real…

never 1 2 3 4 5 6 7 almost all the time

Please enter your comments. Things you could consider are:

- Aspects of the experience that made you respond as if it were real.
- Aspects of the experience that led you to make responses that would have been unrealistic if the situation depicted had been occurring in reality.
- Aspects of the situation that suddenly disturbed your experience of being in the interview.
- Aspects of the experience that helped or hindered you achieving your task.
- Aspects of your feelings towards the experience
- …

Write your answer in the space below:

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