THE DESIGN AND IMPLEMENTATION OF THE TELEPATHIC IMMERSIVE VIRTUAL REALITY SYSTEM

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ABSTRACT

This paper describes a project which has a focus on immersive virtual reality (IVR) as an experimental environment and medium for telepathy. IVR denotes the use of three-dimensional computer graphics technology to generate artificial environments that afford real-time interaction and exploration. These are intended to give the user an impression of being present ('telepresence') or immersed in a computer-generated world. A sense of immersion is promoted through the use of head mounted displays (HMDs). These present stereo images and sound to create a perceptually encompassing computer environment. An instrumented data glove allows participants to interact with virtual objects. We argue that IVR has a number of features which make it well suited for the study of telepathy, including a higher degree of experimental control, the co-location of senders and receivers, and the opportunity for more 'natural' and meaningful (to participants) experimental trials. In the early stages of the project we have focussed on developing an immersive virtual environment (the Telepathic Immersive Virtual Environment, or TIVE) which acts as the experimental environment for both 'Sender' and 'Receiver' in the later telepathy trials. This environment looks like a room: for example, it has a door, a window, a chair, a bookshelf and a potted plant. During the experimental trials the bookshelf is filled with four objects. These objects are interactive; that is, both Sender and Receiver are able to pick up and manipulate the target object. In addition the Receiver can also handle three other objects which form part of the target set (the Sender does not see these additional objects). As the Sender and Receiver handle an object in the TIVE they hear a sound evocative of that object. Having constructed the TIVE our work now focuses on two telepathy studies. In these studies the Sender tries to communicate to the Receiver by telepathic means the identity of an object randomly chosen from a set of four (the set is in turn randomly chosen from a group of four sets). Within this paper we describe the general procedure for our telepathy studies using the TIVE. This includes the computerised random process of target set selection (and of selecting which object in the set acts as the target), and the use of gesture recognition for object selection and de-selection. We conclude the paper with some indication of our future plans for the TIVE.

INTRODUCTION

In an earlier paper (Murray, Simmonds & Fox, 2005) we described the embryonic stage of our intention to use immersive virtual reality (IVR) in the study of telepathic communication. In the present paper we describe in much more detail the subsequent design and implementation of an immersive virtual environment constructed in order to explore telepathic communication in a manner which circumvents or minimizes some of the methodological problems associated with previous work in this area. Two major methodological problems which face experimental psychology in general, and with which researchers of ostensibly paranormal abilities have to engage, are (1) balancing experimental control with ecological validity and (2) lack of replication. The described project utilizes a novel technology, namely immersive virtual reality (IVR), as a research tool to overcome some of these difficulties. We argue that IVR has a number of features which make it well suited for the study of telepathy, including a higher degree of experimental control whilst also maintaining a relatively high degree of mundane realism (and consequently providing the opportunity for more 'natural' experimental trials), the co-location of senders and receivers, and the possibility of replication studies.

Project Background and Conception

Our intention here is to give an indication of the previous research literature (rather than an exhaustive review) on telepathy and general extrasensory perception (GESP), along with some of the problems which emerge in research on this topic. To this end we present literature which demonstrates well, some of the themes which emerge in the broader empirical research on telepathy and the demonstration of psi. (We take here Smith's (2003; p.69) definition of 'psi' "to refer to apparently anomalous processes of information transfer".) We will avoid here a discussion of the problems in distinguishing telepathy from other possible explanations of psi phenomena, such as clairvoyance and precognition - although these issues would be addressed in any research outputs (see Broughton (2002) for a discussion). We will conclude with a description of Immersive Virtual Reality and briefly outline the advantages that this technology poses for research into telepathy before detailing the research project.

Previous telepathy research

One promising line of research to emerge recently in regards to telepathy is that of 'telephone telepathy'. Sheldrake and Smart (2003) conducted an experiment on telephone telepathy with senders and receivers located several miles apart. Participants (n=4) were required to guess who was calling (from four potential callers) each time the telephone began ringing. In 271 trials conducted 45% of guesses were correct (25% were expected by chance); this rose to 61% when the caller was familiar, and dipped to 20% when unfamiliar (although a response bias was evident - see Schmidt, Muller, and Walach, 2003 for a critique, and Sheldrake, 2003, for a reply). In a subsequent study on telephone telepathy Lobach and Bierman (2004) found the emotional bond between participants and persons making the telephone calls to be positively correlated with correct guessing for five of six participants.

In a recent study Schmidt, Muller and Walach (2004) failed to replicate the findings of Sheldrake and Smart. One possible reason for this (amongst several) provided by the authors is that their own experiment took place in a room provided by the experimenters rather than in participants' homes as in the study by Sheldrake and Smart (2003). Schmidt et al. suggest that this change may mean that the phenomenon takes place in more 'natural' conditions (such as participants' own homes) and not under more 'artificial' conditions (such as the unfamiliar experimenter's room).

A study by Sanders, Thalbourne and Delin (2000) is similar to a number of studies which although failing to find a 'hit' rate above chance, do find higher rates of success to be related to a number of variables. In Sanders et al.'s study, 88 subjects aged 18-52 years old took part. Senders were required to "transmit" one of four different emotional states or names (excitement, serenity, anger, or fear) to a Receiver in an adjacent room. The sender/receiver roles were then reversed. Each subject completed 30 trials as sender and 30 as Receiver. Level of hitting did not deviate significantly from chance, but the Senders' transliminality scores (defined as "susceptibility to, and awareness of, large volumes of imagery, ideation and affect - these phenomena being generated by subliminal, supraliminal and/or external input") were significantly and positively related to hit-rate. Similarly, the Receivers' confidence of response and the sureness of abilities of both Senders and Receivers were significantly and positively related to level of hitting.

The possibility of mind-reading in intimate relationships has been examined by Thomas and Fletcher (2003). Their experiment involved perceivers carrying out mind-reading tasks of multiple targets at different levels of acquaintanceship (50 dating couples, friends of the dating partners, and strangers). They found that mind-reading accuracy was (a) higher as a function of increased acquaintanceship, b) relatively unaffected by target effects, (c) influenced by individual differences in perceivers' ability, and (d) higher for female than male perceivers. The authors concluded that the nature of the relationship between the perceiver and the target occupies a pivotal role in determining mind-reading accuracy.

As Bem, Palmer and Broughton (2001) note, "The existence of psi-anomalous processes of information transfer such as telepathy…continues to be controversial." Indeed, Rhine (1974) wrote of telepathy as an "untestable hypothesis", and advocated that research on telepathy "be indefinitely shelved until a conclusive test design is discovered." However, some researchers have found support for the existence of telepathy, with much of this evidence coming from ganzfeld studies.

The ganzfeld has become the most favoured and successful experimental method for the assessment of general ESP performance, such as telepathy, in modern parapsychology (Bem, 1993; Milton, 1999). This method is comprised of three stages, the preparation period, the sending and receiving period and the judging stage. The procedure involves a telepathy 'sender' and 'receiver'. The Receiver sits and relaxes in a reclining chair in a room, which is acoustically isolated or sound-attenuated. Translucent halved ping-pong balls are then taped over the Receiver's eyes (which are kept open during the session) and a light directed toward the eyes to create a uniform field of unpatterned vision. The visual field in the ganzfeld is red in the majority of the ganzfeld literature (e.g., Avant 1965; Bertini et al., 1964; Honorton & Harper, 1974) although some researchers employ other colours (usually white light, e.g. Braud et al., 1975). Headphones are placed over the ears through which the Receiver usually hears white noise, which produces a homogenous auditory field.

Prior to hearing white noise, the Receiver typically listens to a series of progressive relaxation instructions, which are employed to further reduce internal somatic "noise". The Sender is located in a separate room, which is also acoustically isolated. The role of the Sender is to concentrate on a target (often a visual stimulus) which has been randomly selected from a large pool of such stimuli. The Receiver is encouraged to provide a continuous verbal account of any mental imagery and thoughts experienced during the 'sending period'. This lasts for about half an hour, after which time there is a review of the imagery experienced during the sending period, followed by the judging stage. Here, the Receiver is presented with a choice of usually four stimuli, one of which is the target. The stimuli are arranged into four orthogonal sets. Without knowing the identity of the target, the Receiver is then asked to rate the degree to which each of the four stimuli matches the imagery and mentation experienced during the ganzfeld period. In some experimental designs, independent judges address the similarity between the target and the imagery of the Receiver (Milton, 1991). A 'hit' is scored if the Receiver assigns the highest rating to the target stimulus (Bem & Honorton, 1994). ESP or an anomaly ('psi') is inferred from performance (the number of correct identifications of the 'target' or hits), which is significantly above what would be expected by just guessing, chance (or below chance in psi-missing).

The current climate in parapsychology is one of an interim phase of self-assessment and evaluation regarding the future of the ganzfeld. This is in the wake of the publication of a meta-analysis of the results of recent ganzfeld experiments that found a null overall effect size in terms of ESP performance (Milton & Wiseman, 1997; 1999). Meta-analysis is a tool for statistically synthesising large bodies of work to ascertain the true level of the replicability of an effect (Utts, 1991). It is a means of addressing a database in a way that does not simply add up the number of statistically significant outcomes, but considers the effect size (a measure of the outcome of a study which also incorporates sample size and the power of a study). The Milton and Wiseman (1997; 1999) findings challenge the results of several previous, meta-analyses undertaken on ganzfeld studies which yielded significant outcomes (Bem & Honorton, 1994; Honorton, 1985; Hyman, 1985; Radin, 1997), and they argue that there is not a replicable psi ganzfeld effect. Certain authors conclude that there is a real effect (e.g., Navarro and Lawrence, 2002; Storm and Ertel, 2002) while others continue to assert that there is no real effect (e.g., Milton & Wiseman, 2002). (It should be noted here that there is considerable debate on the role of experimenter effects in facilitating or inhibiting performance in psi-related tasks. For example, see Wiseman & Schlitz, 1997, 1999; and Watt & Ramakers, 2003).

Parker (2003) suggests that the ganzfeld controversy is currently unresolved and any resolution is difficult due to the unacceptability of the phenomena to mainstream psychology. Palmer (2003), on the other hand, reviewed the literature and concluded that when one considers the entire ganzfeld database there is statistical evidence that the ganzfeld has provided good evidence for ESP. It may be that the effects could derive from normal sources, although critics of the field sometimes agree that normal explanations are implausible in accounting for the observed significant effects (e.g., Palmer, 2003).

Characteristics of targets in ESP research

Although it is often unclear whether the source of ESP is an aspect of the agent's mental processing of the target or some aspect of the target itself (Morris, 1978), some researchers have argued that the nature and the way that the target is experienced by the Sender should be considered in more detail in ESP investigations. ESP experiments vary in the extent to which an agent is active or passive; they may focus on the target material and try to communicate it to the percipient or they may be less actively oriented to the target material (Morris, 1978).

Target materials as employed in the ganzfeld for example have often been purely visual; most researchers have employed pictures or video clips, while some researchers have employed objects and geographical locations as targets (Milton, 1991). It has been suggested that psi-conducive targets are more dynamic and multi-sensory and may have a psychological impact on the Receiver (Delanoy, 1989). Target types have comprised both dynamic and static stimuli. Honorton et al. (1990) described dynamic targets as comprising films, documentaries and cartoons, while static targets are comprised of art-work, photographs and magazine advertisements.

Several authors have found a relationship between psi-hitting and aspects of the target. For example, Parker, et al. (1998) found a suggestive relationship between emotionality and effects of change in emotional tone of target material and psi-hitting (in line with May, Spottiswoode and James' findings regarding target entropy relating to psi, 1994). Dalkvist and Westerlund (1998) found a negative relationship between target emotionality and psi-hitting in a forced choice design. However, this was not replicated in a recent experiment (Dalkvist and Westerlund, 2004). Attempts to address the nature of a good target have demonstrated that there is a preference for dynamic target clips compared to static ones (Honorton et al, 1990), and a trend toward a preference for complex (colourful) target clips over simple (black and white) targets (Watt, 1996). These relate to perceptual-like and emotive experiences that are reported in the real world. It is of interest that real events and locations were successfully employed as target in the "remote viewing" experiments conducted by Targ and Puthoff and other researchers in the 1970's (c.f. Tart, Puthoff & Targ, 2000). The dream ESP series at Maimonides (e.g., Ullman, Krippner, &Vaughan, 1973) were also very successful in terms of ESP outcomes (see Sherwood & Roe (2003) for a review of dream ESP studies conducted since that time). It is of note that here the agent often attempted to act out aspects of the pictorial target material. The above literature suggests a need to develop and employ more realistic target material in future assessments of ESP in the laboratory, and to enhance the target experience for the Sender or to increase the reality of the target experience for the Receiver.

What the brief review above highlights is that:

1. An overall above-chance effect is generally not found in studies on telepathy (providing support for the arguments that either telepathic ability is not normally distributed in the population, or that telepathy does not exist), *although this is a source of debate in relation to the body of ganzfeld research*;
2. A number of psychological variables or characteristics do appear significantly correlated with the likelihood that a person will be successful in a telepathy task (providing support for the argument that there is a subset of individuals in the population with telepathic ability);
3. Actual and perceived characteristics of the experimenter are indicative of the likelihood that a significant effect will be observed in experiments in a GESP experiment.
4. The experimental environment may have the potential to increase or decrease the likelihood that telepathy will be demonstrated.
5. Aspects of the target seem important in the 'success' of some ganzfeld studies; more complex target material tends to play an important role.

Problems with research on telepathy

The research described here is built upon a particular problem which can be identified with telepathy research and one which until relatively recently was impossible to overcome: namely, the dislocation of Sender (S) and Receiver (R). In extant research S and R are separated by physical space, be they separate rooms or buildings in a research institution, or in their own homes several miles apart. S is required to try and transmit some information (a name, a picture, an emotion, etc.) and R is required to identify the target from a pool of possible targets. If over the experimental period the number of correct 'guesses' is above chance then this is interpreted as support for the possibility of telepathy, ESP, or psi.

Much experimental research in psychology involves methodological choices about experimental control and ecological validity. Concern with the former arises from the importance placed on the precise manipulation of independent variables, while the latter emerges from an emphasis for experiments to approximate as close as possible situations which are experienced in day-to-day life (Aronson and Carlsmith, 1969). Optimal experimental designs which seek to control extraneous variables usually involve laboratory environments and stimuli which are simple and 'unrealistic'. This is because as the complexity of the experimental environment and stimuli increase the experimenter finds it more difficult to conduct precise manipulations of independent variables and to control extraneous variables.

However, one reason for inculcating ecological validity or mundane realism in experiments is to aid participants' full engagement within experimental situations and to increase their sensitivity to manipulations of independent variables (see Korn, 1997)[1], and as a consequence increase the degree to which such manipulations affect participants as intended. However, one drawback of increasing mundane realism in experimental psychology is that this is accompanied by a loss of experimental control.

In many areas of psychology, such as social psychology, researchers are increasingly turning towards field studies at the expense of control. The experimental procedure has been argued to interfere with such abilities as telepathy, particularly as it presents an unnatural technique for demonstrating this ability; telepathy is often experienced in a spontaneous and less 'clinical' manner. However, within psychology in general, laboratory studies, with their associated sense of control, continue to hold much more respect and prestige. This is particularly important for studies of psi, which academia in general and psychology in particular regards as 'unacceptable' and for whom only the consistent replicability of an effect would sway their opinion.

One way in which the unnaturalness of the experimental laboratory may be alleviated would be if S and R could experience the same environment within which the target is located. If they were allowed to interact with the target pool (such as a book, a vase, or a chair) this might also facilitate both the acts of sending and receiving. This would also go some way to addressing some of the problems with telepathy research identified by researchers such as Braud (1982), who argued against a purely visual transfer model of telepathy. This move to more complex (on a number of levels) target material would also seem supported by the literature reviewed earlier (e.g. Honorton et al., 1990; Watt, 1996). Personal handling of target pool objects by both S and R might be expected to add other aspects to the telepathic communication process usually absent in the methodological design of research on this topic[2]. As the relationship between S, R and the target pool objects becomes more interactive this might facilitate the transfer of emotions, meanings and experiences that better convey what these are. An object which can be handled might be expected to make accessible the personal meanings, purposes of use, and so on, of the object for S and R than might possibly be achieved via a static (or even moving) image or written name (which are more commonly used in telepathy research studies).[3]

However, there are a number of difficulties with the above proposal. First, having both S and R in the same place and time as when the target is available introduces the possibility of fraud and sensory leakage. R could enter the room after S has left, but this still allows the possibility of fraud, and has the added drawback of the temporal separation of S and R's involvement in the experimental trial. These problems may seem insurmountable; however we believe recent technological advances provide a remedy for these problems. Such a technological advance is Immersive Virtual Reality.

[1] Fox (2005) notes that it is an assumption that participants are actually 'participating' in ganzfeld experiments, at least in the manner desired by the experimenter and what might be most conducive to demonstrating psi effects. We would add here that there is a need to make the task stimulating and engaging for both Sender and Receiver in order to maximise such participation.

[2] Though note participants attempts to act out pictorial aspects of target material in remote viewing studies discussed earlier.

[3] Such a view would find support from work in ecological psychology, particular Gibson's (1986) work on optical flow and affordances.

Immersive virtual reality and its potential for telepathy research

Virtual reality (VR) denotes the use of three-dimensional computer graphics technology to generate artificial environments that afford real-time interaction and exploration. These are intended to give the user an impression of being present or immersed in a computer-generated world. Such worlds are often very different from the habitual physical world, and may be governed by different programmable laws than physical reality (for instance gravity and embodied capabilities are often manipulated). While virtual environments can be presented on desktop computer displays, a sense of immersion is often promoted through the use of head mounted displays (HMDs, see Figure 1). These can present stereo images and sound, combined with haptic and vestibular displays, to create a perceptually encompassing computer environment. A sense of 'presence' or telepresence (presence-at-a-distance), of feeling 'there' in a virtual environment is, perhaps, the ultimate aim of VR research. This calls for a dampening of awareness in 'reality' and a heightened 'acceptance' of the surrounding virtuality (Sheridan, 1992).

Researchers of ostensibly paranormal abilities have been at the forefront in embracing and incorporating into their research the developments and increased sophistication in technology (see Broughton (1993) for example). One example of this is the testing of general extrasensory perception (GESP) which began using Zener cards, then photographs, video, and more recently computers and digital ganzfeld. Such technological developments have aided researchers in increasing mundane realism while minimising the negative impact to experimental control. Immersive Virtual Reality (IVR) has been documented as providing participants with a compelling sense of personal, social, and environmental presence (Witmer & Singer, 1998). Blascovitch et al. (2002) outline how the use of IVR in experimental psychology circumvents a considerable amount of the problem involved in making choices about control versus mundane realism. The researcher gains optimal control over the experimental environment and actions that take place within it, while increasing the mundane realism of the experiment and the full engagement of the participant.

In support of the use of virtual environments for facilitating ESP performance, the environment around the target has often served as part of the target, even if this was not intended by the experimenter (Morris, 1978). This implies that the mind of the Receiver may seek to put the target into the wider context, e.g., of the room in which the target material is being played/viewed. Real world ESP experiences often involve an event which occurs for one person (the agent) which is then experienced in some form by another person (the percipient). These experiences are often meaningful or emotionally affective to the percipient and agent (c.f. Irwin, 1999). In modern ESP experiments free response methods have been adopted to increase the level of ecological validity with regard to every day psi experiences. However, target materials still seem somewhat limited and may not often accurately mimic real world ESP. IVR, with its dynamic, three-dimensional representation of stimuli which can be handled by both Sender (S) and Receiver (R) in identical virtual environments, would seem to offer an opportunity to address these issues.

Immersive Virtual Reality and Replication in telepathy studies

The issue of replication is a pervasive problem in psychology research in general, with many journals uninterested in publishing replication studies, particularly when there is a failure to replicate (the so-called 'file drawer problem', Rosenthal, 1979). Researchers and publication outlets in the field of parapsychology and psychical research have been more open to this problem, in part due to the stronger application of the principles of reliability and validity often placed on such research by critics, and replication attempts are more commonly reported.

Here we want to consider an issue relating to replicability, particularly in relation to research on telepathy, which the proposed research is intended, in part, to address. The replicability of experimental findings has been viewed by many researchers of psi as an important goal in establishing parapsychology as a 'legitimate' avenue of scientific inquiry (e.g., Shapin & Coly, 1985; Utts, 1991). One reason why replication studies in many areas of psychology are not attempted is due to the difficulties that interested researchers have in using and carrying out the same methods and procedures as (detailed by) other researchers. Researchers of ostensibly paranormal abilities in particular have stressed the need to report such details as fully as possible, and this has aided attempts to replicate significant findings. However, even when researchers provide informationally rich and accurate descriptions these attempts are hampered by such problems as differences between the physical properties (size, colour, and so on) of researchers' physical laboratories

Replicability, one of the hallmarks of a science, remains an issue as there are inconsistencies in the effect sizes found across experimenters and laboratories. This weak level of replicability leaves parapsychology open to criticism from the wider scientific community. Where experimenters follow Honorton's original recipe for a standard ganzfeld, there are better results in terms of ESP performance (Bem, Palmer & Broughton, 2003). However, one reason sometimes advanced for the failure to replicate statistically significant parapsychology studies is that replication studies sometimes omit important procedural features which are present in studies showing significant findings.

With the use of IVR in experimental psychology the possibility of replications or 'near-perfect' replications increases (Blascovitch, et al., 2002). Because software is 'portable' and the necessary hardware can be easily purchased, identical experimental situations and procedures can be shared with ease. Virtual environments can be easily shared between researchers and across laboratories, increasing the opportunity for both cross-sectional replication and for more representative sampling (Blascovitch, et al., 2002). This means that experiments can be carried out concurrently in multiple networked laboratories. While the research project described here does not present an immediate solution to the above problem, it does advance a technology which in the long term we argue will become a pervasive research tool in experimental psychology in the near-future, and which presents researchers interested in the scientific study of ostensibly paranormal abilities in particular with techniques to overcome some of the inherent limitations associated with conducting this work. Blascovitch et al. (2002) argue that, just as the increasing proliferation of the Internet provides new opportunities for on-line research with demographically documented sampling frames, as IVR technology migrates from academic and entertainment contexts into the home, the possibility of conducting experiments on participants who are representative of the populations to which researchers wish to generalise their findings will also increase.

To briefly summarise, the advantages that we believe IVR offers to researchers of ostensibly paranormal abilities or psi include the optimisation of control and mundane realism, the fuller interest and engagement of participants, the possibility for replicable studies, and the enhancement of target stimuli for optimal effect. In the following section of this paper we provide technical details of the TIVE.

IMMERSIVE VIRTUAL TELEPATHY SET-UP

Physical Spatial Arrangements

Our current study employing the TIVE takes place in two rooms in Coupland 1 Building, Division of Psychology, University of Manchester, arbitrarily called 'Study Room A' and 'Study Room B'. Room A is always the Sender's (S) room, and room B is always the Receiver's (R) room. (The possibility of sensory leakage is minimized as these rooms are approximately 150 feet apart, on different floors, and have 7 doors in between them.)

Immersive Virtual Reality Equipment

A V6 stereoscopic head-mounted display (HMD) is used to transmit the visual elements of the virtual environment to the participants [http://www.virtualresearch.com/techV6.htm]. This has a 640 x 480 (307,200 colour elements) pixel resolution per eye, and a 60° diagonal field-of-view. The participant is able to 'look around' the IVR by making corresponding movements of their physical head. The Sender (S) hears the sound made by objects via an in-ear phone (left-ear). They are also able to hear (with their right ear) the spoken mentation of R via speakers placed close by. The Receiver (R) hears the sound made by objects via headphones built in to the V6.

The physical interaction of participants within the IVR is achieved via the use of an instrumented glove which allows the 'handling' of virtual objects. The system currently in use employs a 5DT-14 wireless lycra dataglove [http://www.5dt.com]. The glove facilitates the measurement of finger flexure (2 sensors per finger) as well as the abduction between fingers. This enables participants to interact with virtual objects but does not provide tactile or haptic feedback. A sensor attached to an elasticated band is placed around the wrist, and one around the elbow. A third sensor is attached to the top of the HMD. A Polhemus cube is placed on a tripod approximately 11/2 feet in front of the participant. This device relays the information received from all three sensors to a Polhemus Fastrak box which translates them into corresponding movements of the participant's virtual body in the virtual environment.

The Polhemus Fastrak contains some hardware filters to stabilize the positions and orientations of the sensors. However, in some circumstances like magnetic interferences, some jitters can appear which is detrimental to any experiment. Therefore, we have added the software "Infinite Response Filter" to the sensors, which has the effect of smoothing the input data. The latency associated with any kind of filtering is here reduced by smoothing over the two previous frames only.

Calibration becomes an important issue when establishing a link between the virtual and the real world. By default, the Polhemus sensors are not calibrated at all, and any magnetic interference has the effect of distorting the readings. Calibration has then to be achieved in the software, using some known correspondences between the real and the virtual world. In a calibration step, the sensors are placed consecutively at a series of known locations. The program then records their locations as given by the Polhemus Fastrak, and computes the correspondence function. Other locations are interpolated, which means that the matching between real and virtual world could not be equally accurate everywhere.

Construction of the Virtual Body Representation

The positions of the sensors are used to control a model of the human body. The kinematic model is a tree of joints and bones which defines the pose of the model, as opposed to its appearance (colours, etc.). Each joint of the model is then defined relatively to the previous joint in the tree. For example, the position of the forearm is defined relatively to the arm. The only free parameters are then the relative rotation angles of the joints. After a careful parameterization avoiding singularities, the joint angles encode the pose of the body. The transformation between joint angles and global positions is efficiently implemented using quaternions.

Placing constraints on the joint angles allows impossible poses to be avoided. The appearance of the body is modelled by a polygonal mesh, attached onto the underlying kinematic model. At each frame, the coordinates of the polygons constituting the mesh are then updated to reflect the movements of the kinematic model. In order to model properly deformable joints, the skin mesh cannot be rigid, but has to be deformable and influenced by more than one joint. We use a technique called "Mesh-Skinning", which allows a vertex of the skin mesh to be influenced by an arbitrary number of kinematic joints. The position and the normal of a given vertex are then computed as a weighted sum of their values as if it was attached solely to one kinematic joint at a time. This technique is sufficiently simple for real-time computations, but nonetheless gives realistic results.

Immersive Virtual Reality Environment

A virtual reality environment has been created for use in this project. The environment itself resembles a virtual room containing four walls, ceiling, floor, a door, two windows, and a wall mounted shelving system, similar in appearance to a bookshelf. The operator is free to turn around and take in a 360^0 view of the room. They are able to see their virtual body in a similar fashion to the way we see our own real bodies, i.e. arms, legs and parts of the torso, but are unable, for instance, see their own face, head or back. Movement is restricted within the environment to motions that only serve the purpose of the experiment. So, a person may move their arms and fingers and legs, but they cannot 'virtually walk' anywhere around the room. The target objects appear in the virtual room on the shelving mentioned above. Targets are selected from the shelf via a gesture of the hand (the participant bends their thumb in towards the palm of the hand) that the equipment registers as a selecting gesture (this will described in more detail in the procedure section). When an object is selected, it moves from the shelf and affixes itself to the participant's virtual hand. They are then free to interact with the object (more details of this will be described in the procedure section) (see Figure 1). It must be clearly noted that at no time is the Sender or the Receiver able to see their experimental partner's virtual body in the room with them. Essentially, although the environment they inhabit is identical in nearly all respects, it should be viewed and treated as two separate rooms.

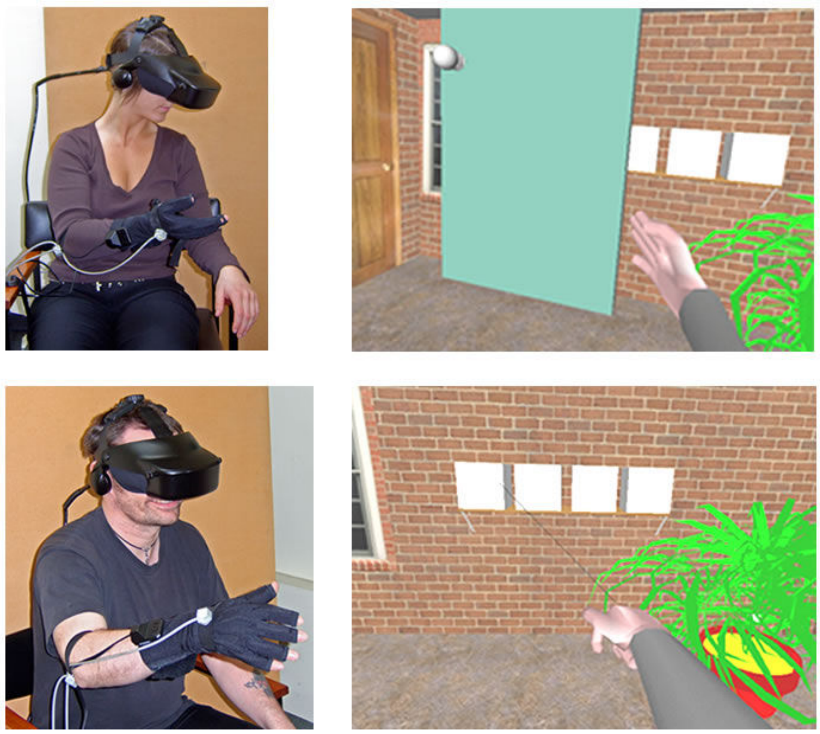

Fig. 1 A Sender (above left) and Receiver (below left) using the demonstration set in the Telepathy Immersive Virtual Environment.

Computer Equipment and Set-up

The experimental set-up is identical for both the Sender and Receiver, in their respective rooms, as follows. For each participant we use two computers. The first is a small-form-factor "XPC" from Shuttle Inc. [www.shuttle.com] with a 1.4GHz CPU and 512Mb of memory, running Ubuntu Linux [www.ubuntu.com]. This computer hosts the V6 stereoscopic head-mounted display, computer monitor, Polhemus Fastrack and the data-glove.

The software running on the Shuttle was designed and implemented by the authors for this project. The software uses C++ for logic and control, OpenGL for graphics [www.opengl.org], and OpenAL for sound management [www.openal.org]. The software communicates with the identical Shuttle in the other (Receiver's) room using a standard Internet "socket" library, connecting with the other Shuttle via a standard ethernet (Internet) connection. This receives instructions from the Sender's computer /software. Similar to the master computer, real time actions in the virtual world are displayed on computer's monitor, again enabling the experimenter to view and record what is happening.

The Sender's first computer governs the selection and randomization of target pools, sets and objects. It also governs the presentation of objects during the judging phase. We base the random selection of objects on the standard Unix/C system function "rand", which returns an integer selected from a pseudo-random sequence initialized the system called srand(seed) which is seeded with the current system time (in milliseconds) at which the software was started. Thus for every run of the system (i.e., for every trial) a completely different pseudo-random sequence is guaranteed.

The second computer in each participant room is a standard office PC running Windows XP. This computer hosts the Skype voice-over-IP telephony software [www.skype.com] which enables the Sender to hear the mentations of the Receiver (via a microphone), via Skype also running on the PC in the Receiver's room. In the original experimental design, we intended Skype to run on the Shuttles, but during system testing we found that this was not technically possible, because the Skype software "locked" the Shuttle's soundcard, preventing the OpenAL software from functioning and producing the sounds associated with each object. A solution to this problem was not achievable within the project timescale, and thus led to the deployment of the additional PC to host the Skype software. The experimenters are also able to communicate with one another using the text 'chat' function of Skype. This allows the experimenters to synchronize activities, such as when Experimenter 1 (with the Receiver) signals that they are stopping the trial and beginning the judging procedure (during which the Sender's speakers are turned off by Experimenter 2). After each completed study the record of each Skype session, containing the dialogue between experimenters, is saved for future reference.

In order to translate participant gestures into commands in the virtual environment we wrote software to recognize two simple glove gestures only: the recognition of a movement of the thumb into the open palm (to select an object from the virtual shelf), and the recognition of a fully closed palm (a fist, to replace an object back on the virtual shelf). In order to cater for differing hand and finger sizes among subjects, we provided a simple "sensitivity" control (see Figure 2) which the experimenter could use to adapt the software to the participant, and such adaptations were made before the start of the experiment proper. The Graphical User Interface (shown in Figure 2) allows the Sender's experimenter to input a participant-pair ID, to stipulate their participant is the Sender (in the Receiver's room the experimenter would just check the Receiver role option, then press start), and to select the object set. We also have options to change the coloring of participants clothing as it appears on the virtual body, along with the length of their sleeves and their skin color. In our present work the default settings indicated in Figure 2 are used.

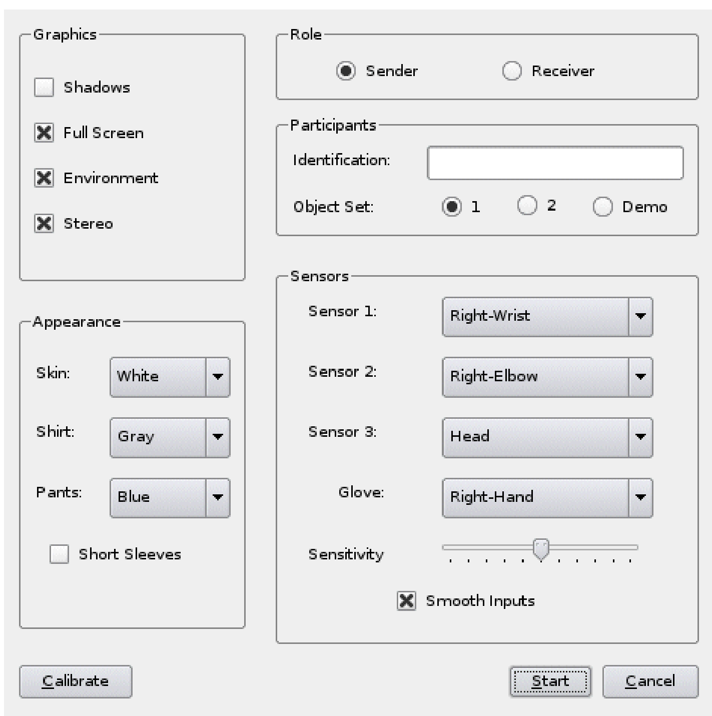

Fig. 3 The Graphical User Interface for the Telepathy Immersive Virtual Reality Environment.

Target Pools and Objects

One demonstration set (comprised of four doors) and two separate target pools (in total comprising of eight different sets and a total of thirty-two objects) have been generated especially for this project, one pool for Study 1 and the other for Study 2. In order to familiarize participants with the experimental procedure, and the procedures for selecting and de-selecting objects, S and R first see a demonstration set. This is a set of four doors, with different colours, and different knocking or bell-ring sounds. For Study 1 there are four sets of four objects which collectively make up the target pool for study 1, making a total number of 16 objects. For Study 2 a second target pool consisting of another four sets is used. Each set contains four objects that are entirely different from the objects in the four sets used in study 1. Again, each object has its own associated sound, making a total number of 16 objects in use in Study 2.

The TIVE System in Use

Before the experiment begins, both participants receive a set of verbal, standardized instructions about what they have to do in this part of the experiment. Both S and R are asked to put on the head-mounted display and instrumented glove. The equipment is adjusted to the participant's comfort and calibrated in order to ensure that the instrumented glove can pick up the necessary gestures required to select objects (described in detail later).

In each room S and R first experience the demonstration set. During this time there is a two-way audio link between the Sender and Receiver rooms. Once participants feel comfortable with the task and equipment the microphone in the Sender's room is physically disconnected for the remainder of the study. Study 1 then formerly begins. The Sender's computer selects one of the four object sets randomly from the study 1 target pool. It then presents the four objects in the chosen set in random order on the virtual shelf in each of the virtual environments (the same random order in each environment). In the Sender's environment, they see one object which is randomly selected as the target from the object set, and three square opaque panels. The placement of the target object and panels is randomized. In the Receiver's environment they initially see four square opaque panels. These panels hide the objects from the view of both participants. Prior to the trial the Sender is briefed that, once the target object has been presented, they should then focus their attentions on the target and ignore the three remaining objects on the shelf, which shall remain hidden. This method is intended to minimize contamination of the Sender's thoughts by visual experience of the other objects on the virtual shelf (however, they can hear the Receiver's verbal description of these objects if they choose to provide them). In order to facilitate a more complete focusing of attention on the target object, the Sender is free to explore the object by pointing at it and making a gesture with the hand that the instrumented glove interprets as a selecting action. The object then comes off the shelf and affixes itself to the Sender's virtual hand. At the same time an associated sound is played through the headset headphones on a loop for as long as the Sender manipulates the object. The Sender is then free to interact with the object, turning it around, looking at it from different angles, and is able to carry out object-specific actions. For instance, if the object was a cup, then the Sender can simulate drinking motions by lifting the cup up to the mouth. When the Sender is finished with the object they are able to perform a gesture (making a fist) which returns it to the virtual shelf.

Concurrently, in the Receiver's virtual environment, the participant is free to explore all four objects in the same fashion as the Sender. By pointing at one of the opaque panels and making a selection gesture, the partition disappears and the object comes into view on the shelf before traveling and becoming fixed to R's hand. Whichever object the Receiver chooses to interact with, the relevant associated sound is played through the headset headphones on a loop for as long as the Receiver manipulates the object. When the Receiver is finished with an object they perform a (fist) gesture which returns it to the virtual shelf and replaces the opaque panel. They can then select another object using the same procedure as before.

Throughout the trial period the Sender concentrates upon the target object whilst the Receiver is able to manipulate any of the objects as they choose. Both participants are encouraged to verbalize their impressions, feelings and thoughts as they try to send and receive respectively. A one-way audio connection between the Sender and the Receiver allows the Sender to hear the Receiver's spoken aloud mentation. This provides the Sender with real time feedback on how well (or not) they are performing. As the set up is one-way, the Receiver is not able to hear anything the Sender is saying.

At the end of the first trial Experimenter 1 (with the Receiver) signals to Experimenter 2 that they are stopping the trial using the text 'chat' function of Skype. Experimenter 2 then switches off the speakers in the Sender's room and quits the Telepathy Virtual Environment. Judging in the Receiver's room does not begin until the Experimenter has received confirmation via the Skype chat facility that the speakers in the Sender's room are switched off. The Sender is then free to remove their HMD and signs a sheet to confirm what the target object was. The Receiver, however, keeps their HMD on whilst they carry out the judging procedure. During this procedure the experimenter presses a 'reveal' function on the keyboard and the Receiver is able to see all four objects simultaneously in the order they appeared on the shelf. First, the Receiver is asked to indicate whether they feel that there are any items which are definitely not the target (they may choose between 0-3 of the items). The Receiver is then asked to rate each object in terms of how much they feel each object is the target. This is expressed as a percentage (0-100) for each object. Receivers are asked not to duplicate their confidence ratings (they give a different numerical rating for each object), which the experimenter writes onto the judging sheet (with each object having a unique rating). These confidence ratings are then used to derive ranks for each object.). Once the judging procedure is complete, the Receiver removes their HMD and completes the first of their Presence questionnaires. The experimenter with the Receiver then confirms with R what their first choice is before relaying this to the second experimenter in the Sender's room using the Chat facility in Skype. This information is given to the Sender, and the actual target object is relayed back to the first experimenter in the Receiver's room who relays this to R.

Following Trial 1, the Sender and Receiver reverse roles and perform the second trial. For the current project S and R swap physical locations (However, it is possible to reverse the roles by having the computer in room B make the pool and object selections instead of that in room A). S and R first meet approximately half-way, where they stop and chat with the experimenters about their performance before participant's swap experimenters and rooms. The second trial is essentially the same as the first trial; with the exception that this time the Sender's computer randomly chooses the second object set from the three remaining sets in the study 1 target pool (i.e. the set chosen for use in the first trial will not be available for selection). Following this, participants re-don their HMDs and the second trial begins. The randomization of the order of presentation of objects in the virtual environment and the procedure for selection and manipulation of those objects are all the same as for the first trial. Again, both participants are encouraged to verbalize their impressions, feelings and thoughts as they try to send and receive respectively. However, this is particularly stressed to the Receiver who is aware that the Sender can hear them viia the audio link. At the end of the second trial, the Sender removes their HMD and completes the second of their presence questionnaires. The judging process for the Receiver is the same procedure as for trial 1. The process of relaying R's choice and the identity of the actual target is the same as in Trial 1.

SUMMARY AND FUTURE DIRECTIONS

Within this paper we have described the design and implementation of an immersive virtual environment for the study of telepathy. We have described the particular advantages that this method has over traditional methods for the study of general extrasensory perception. These include the optimisation of control and mundane realism, the fuller interest and engagement of participants, the possibility for replicable studies, and the enhancement of target stimuli for optimal effect.

There are, however, further improvements which we hope to implement in future work. First, we intend to integrate the audio relaying the Receiver's comments with the sounds elicited by the virtual objects in the HMD earphones of the Sender, thus negating the need for speakers during the trial. Second, we intend to incorporate the judging procedure into the software of the IVE, so that participants responses can be recorded akin to how such responses are recorded in autoganzfeld studies (although we believe the current procedures are as sufficient in guarding against human error in recording responses and experimenter fraud). Third, we intend to use animated virtual objects (i.e. objects which have moving parts or parts which can respond to interaction by the participant) to supplement the static (though interactionally available) objects in our present work. In future work we hope to be able to collaborate with other parapsychology laboratories in order to explore issues of replication and experimenter effects.

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