Presence: Experiments in the Psychology of Virtual Environments

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Abstract

Previous research has suggested that presence in a virtual environment (VE) is important for several reasons (Sheridan, 1992; Barfield et al., 1995; Slater et al., 1996). A highly present individual is more likely to behave in the VE in a manner similar to their behaviour in similar circumstances in everyday reality. Therefore, an immersive virtual environment (IVE) may be a useful system for training and skill acquisition, where to train or gain the skill in the real world may be too expensive or dangerous. This formulation of the effect of presence may be used to construct a measure of the degree of presence. Suppose that individuals are placed in an environment which is familiar relative to everyday reality. Those individuals who have a high degree of presence would be likely to exhibit similar behaviours to that in the real world - for example, obeying social conventions, perceived psycho-physical limitations, and egocentric interactions. Those individuals who are less present may be more likely to break these conventions (for example, walking through virtual walls and off virtual cliffs). This paper discusses research in presence within IVEs and presents an experiment using a measure of presence based on observable behaviours of people placed in a VE that is a representation of a familiar environment.

Keywords
Virtual reality, virtual environments, presence, immersion, acclimatisation

1. Introduction

The psychology of a person who, by interacting with a computer system, becomes incorporated within that system is an interesting area of study from a psychological standpoint. It is also an important area of study for the computer scientist working in the area of virtual environments since internal processes of the user or participant of the virtual environment determine to what degree they will be compelled by what they see, hear, and feel and therefore become immersed into the virtual world. This phenomenon is known as virtualisation and is the 'process by which a human viewer interprets a patterned sensory impression to represent an extended object in an environment other than that in which it physically exists' (Ellis, 1995). This is the basis of virtual environments (VE), an area of computer science research which has gained popular attention over the last five years. The extended object or environment is generated by computer technology and presented in a form which is more readily understood by humans, for example through the synthesis of the visual, auditory, kinesthetic and haptic senses. The technology therefore allows an integration of the human and the computer in a way which is more natural than earlier forms of computer interfaces.

Although the current field of virtual reality is fairly new, the idea of immersion in a virtual environment has been known for some time. It was proposed by Ivan Sutherland in the mid 1960s (Sutherland, 1965) and realised in 1968 with a head-mounted display (HMD) that could present the wearer with a stereoscopic (three dimensional) display of a computer generated world (Sutherland, 1968). The position of the wearer's head was determined by a six degree of freedom mechanical tracker (3 translational, 3 rotational) and relayed to the computer system. This means that virtual objects that would be seen by the participant looking in a particular direction could be determined and displayed by the visual media. This 'ultimate display' however, presented simple wireframe models with no interactions between the subject and the objects. With recent increase in computing power and advances in technology it is now possible to create much more complex environments which can permit multiple participants with complex models of interaction and behaviour. Display systems are now capable of creating three dimensional (directional) sounds which come from within the virtual environment. These are not normal stereo sounds which are often located "within" the listener's head, but are digitally constructed so that the location remains constant (no matter which way the subject turns) and the amplitude varies with distance from the source. A number of devices also exist which can give a degree of tactile and kinesthetic feedback such as gloves and 'body suits'. Virtual environment systems have therefore become a tool for research and work in a variety of ways which were previously unobtainable.

In an ideal virtual environment or, to use the more popular term virtual reality (VR), the totality of sensory information is continually supplied by the computer hardware. We note, however, that most present day virtual reality systems usually display information only in the visual and auditory modalities. Following the definition of virtualisation this information allows for an egocentric frame of reference from which the environment can be described. This is the visual point of view, the auditory location, and the kinesthetic position. It is also the position within the IVE occupied by the human participant. The participant is therefore incorporated within the frame of the environment and his/her movements are reflected in appropriate changes to the information displayed by the computer. This can lead to a sense of presence, i.e. the belief that the participant is present in the environment of the computer generated objects. This is the fundamental aspect of immersive virtual environments that is not possible to induce to the same degree using other computer systems (Slater, Alberto and Usoh, 1994).

In the following sections we present research work in presence and discuss factors which can influence it. We outline the technique of neuro-linguistic programming (NLP) which we have used as a basis for developing experimental questionnaires and the effects of an individual's representational system on their sense of presence within a VE. We also show how proprioceptive reinforcement can enhance presence and present an experiment to test observations of behavioural presence.

2. The Body

An important component of everyday reality which gives us physical presence within the world is the body. Although it is based at the focal point of our world its possession is so obvious that its many functions are sometimes overlooked (Synnott, 1993). It acts as several mediums.

- It is a medium of interaction and its possession permits the ability to change the environment. Given current day technology it is also a tool for manipulation of near and remote sites;

- It is the physical embodiment of self. Through it we gain a personal and social identity of being. We recognise others through their bodies and change our exterior in ways to reflect our personality, moods, social status and individuality;

- It is a medium of communication which allows us to interact with others on a higher level. It is used to convey feelings, ideas, and opinions through sounds and gestures and also receive these from others.

Since sensory information from the outside world is received and processed through the body it also plays the role of an anchor to the world generating the sensory information. That is, by acting on the body the sensory information from the external environment aids in grounding the self in that environment. The physical body, for example, is constantly under the influence of external forces such as gravity. Loss of effect of this force would mean a complete remodelling of the behaviour of the world. Experimental studies have shown a similar rooting in the virtual environment can be achieved by providing the participant with a computer representation of their body (Slater, Usoh and Steed, 1994; Slater and Usoh, 1993). Although it is not necessary for this virtual body (VB) to resemble the participant's physical body precisely, it must, however, function correctly and remain consistent in its response to the participant's movements, i.e. there must be a 1:1 mapping of movements of the physical body to the virtual body. When the participant raises their hand to their face they should see their virtual hand which is attached to a virtual arm leading to their (virtual) body. When they look down at their virtual body they should see their virtual legs with their virtual feet placed on the virtual ground.

3. Proprioception

For virtual reality to work (Stark, 1994) it must be possible to overlay sensory information from interacting with the environment onto the normal *proprioceptive* channels. This is, as defined by Oliver Sacks "...that continuous but unconscious sensory flow from the movable parts of our body (muscles, tendons, joints), by which their position and tone and motion is continually monitored and adjusted, but in a way which is hidden from us because it is automatic and unconscious" (Sacks, 1985). Proprioception therefore allows us to form a mental model of our body and the disposition of its limbs. Given this, the conceptually difficult problem of touching both our eyes, our nose and our mouth using the index finger of the right hand seems almost trivial - even with our eyes closed. The extent to which this mental reconstruction is called upon in everyday life is often not realised until the model breaks down or is lost. It is often said that one never forgets how to ride a bicycle. Without the proprioceptive feedback even walking is not possible.

In a virtual environment sensory information is gathered using the tracking devices placed on the physical human body. This must be on at least the head and can extend to the hands, feet, and joints. This information allows the construction of the computer representation of the human participant inside the environment, i.e. the virtual body (VB). The VB must however map directly to the physical body for visual proprioception to operate correctly.

Given proprioceptive feedback (and appropriately designed virtual environments) it then becomes possible to reproduce psychological and physiological everyday reactions in a computer mediated space. Feelings of stress, anxiety, and tension may be induced[1]. These have been shown in experiments reminiscent of J.J. Gibson's visual cliff experiment (Gibson and Walk, 1960]. Subjects were presented with a scenario where they were placed on a narrow ledge overlooking a precipice several metres deep. They exhibited and reported strong psycho-physiological reactions such as feelings of weakness in the legs, nervousness, and increased anxiety (Slater, Usoh and Steed, 1995).

4. An immersive virtual environment

In this work we are strictly concerned with immersive virtual environments. These are environments where the participant has an egocentric frame of reference, that is the world displayed by the computer system is created with a viewpoint centred at the participants head position. This means that at any time, as the participant turns his/her head, the corresponding generated images should change accordingly to reflect the new direction of gaze. A test of this would be for the participant to turn around by 180 degrees. If they can see the objects behind them in the virtual environment then they are immersed. This is in contrast to an exocentric viewpoint such as on a desktop system where a few degrees of head turn can quickly result in the subject looking off the edge of the screen.

A fully immersive system therefore requires a framework which can fully enclose the participant. This can be achieved within a room where computer generated images are projected onto the walls (Cruz-Neira et al., 1993) or by a head-mounted display (HMD). HMDs are the more popular and are usually helmet-like with two colours monitors mounted so that the left screen image is seen by the left eye and the right screen image is seen by the right eye (Robinett and Rolland, 1992; Teitel, 1990). The images sent to each screen are slightly different and are fused as one by internal processes in the visual system (as in normal vision) so that the wearer sees the displayed objects in three dimensions. The head and hand (and possibly other limbs) are tracked by a wireless electromagnetic system which is able to determine the position and orientation of these relative to an external source (Kalawsky, 1993, pp135-163) The participant can then be placed in a relative position in the virtual environment. Interaction between the participant and virtual objects is made possible using an input device such as a dataglove or a 3D mouse. This will then allow the

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[1] We must stress the importance of appropriately designed experiments. In all studies that we've conducted we have ensured that participants are aware that they are in control of the experiment and can stop whenever they wish.

subject to pick up, move and change aspects of virtual objects such as the radiant properties. In short, it allows the subject to communicate with the computer program through a 3D metaphor.

Immersive virtual environments therefore attempt to reproduce J.J. Gibson's notion of an "ambient (optical) array" (Gibson, 1986). This consists of an arrangement of a nested hierarchy of visual solid angles in the case of an ambient optical array. These visual solid angles all meet at the same apex. The apex corresponds to a position in the environment which may be occupied by an individual - the self. Gibson argued that when an individual in immersed in such an environment, perception of the self is inseparable from perception of the environment. In describing the occupation of a position in the ambient optical array by an individual he says, "When the position becomes occupied, something very interesting happens to the ambient array: it contains information about the body of the observer." (Gibson, 1986, p66). The body of the observer is not disembodied from the self. Again, he writes with regards to the relationship between sensory information and self perception, "The optical information to specify the self, including the head, body, arms and hands *accompanies* the optical information to specify the environment. The two sources of information coexist" (Gibson, 1986, p116).

In an immersive virtual environment the ambient arrays are specified using a model within a computer system that

- generates displays ideally in all sensory systems;
- tracks the body, limbs, head;
- determines the optical, auditory, and other arrays as a function of head tracking.

The system must be able to provide the user with a sense of realism, that is a sense that the environment they are seeing actually exists in some form.

We have previously distinguished between two types of factors (external and internal) which can influence the subject's sense of realism and can contribute to their sense of presence, i.e. "being there" in the virtual environment.

- Exogenous factors (those that are external) are created by the virtual reality system or manifest themselves through the media. These are determined from the hardware and software used to generate the scene and the degree to which they can create a high fidelity environment.
- Endogenous factors, or those that are internal are functions of an individual which determine how the same externally produced stimuli are processed and interpreted by a participant.

We will now discuss these in more detail.

4.1 Immersion and exogenous factors

Although the exogenous factors that influence a participant's sense of incorporation in the virtual environment have been discussed by many researchers (Barfield et al., 1995; Barfield and Weghorst, 1993; Heeter, 1993; Held and Durlach, 1992; Loomis, 1992; Sheridan, 1992), their exact nature and degree still remains unclear. However, they are generally related to the extent to which the environment looks and behaves realistically. They also relate directly to the capabilities or immersive properties of the virtual environment system.

Immersion is a description of a technology and is that physical and software component of the virtual environment system which provides the user with information about the environment. The broader and richer the information produced by the system, the more the system is said to have immersive properties. Immersion is therefore quantifiable - at least to a partial order.

Factors determining the extent of immersion include the degree to which the computer displays are extensive, inclusive, surrounding, vivid and matching (Slater, Usoh and Steed, 1995). A system is more extensive the more sensory modalities it can accommodate. Thus a system which can represent visual, auditory, and tactile information is more extensive than one which has visual information alone. It is inclusive if it is able to shut out external signals (from the real world) and surrounding if it presents information in the virtual world from all directions. In the case of auditory information this would be directional (3D) sounds. Visually this would mean a stereoscopic view which allows the participant to use natural head motions to view an ambient world - by physically turning 360 degrees the subject is able to see all around. The vividness is a function of the richness and fidelity of the information presented. A world which is highly vivid would be displayed in colour using an accurate lighting model. It would contain shadowing and textures and be presented in "real time" so that actions of the participant interacting in the world are reflected immediately as changes in the computer images. Finally matching is a function of body tracking. It requires that proprioceptive actions of the participant in the real world are matched accurately to the virtual world. For instance, a turn of the head to the left should cause an immediate flow of optical data to the right in the VE and the position of objects in the VE should remain invariant both visually and auditorily. We note, therefore, that the higher the degree of body tracking the greater the proprioceptive sensory data match. Through the virtual body proprioceptive feedback can then allow a reinforcement of the match between the physical and virtual worlds.

Given two virtual environment systems presenting the same environment to a user, the first can be said to be more immersive if the corresponding factors of extensive, inclusive, surrounding, vividness and match are greater than the second. We note at this point that immersion can also be affected by a function of interaction and autonomy of virtual objects. These relate indirectly and are mediated through the physical aspects of virtual environment technology, for example computing power. An environment can become more immersive given a higher degree of interaction between the participant and the inhabitants of the virtual world who may be other participants sharing the virtual world.

4.2 Endogenous factors

We have seen that technological capabilities of different VE systems may cause identical VEs to be displayed to different levels of detail. It would be seen as obvious that presented with varying levels of detail of a VE a participant would immediately note the differences. This is not necessarily the case. In (Slater and Usoh, 1994; Slater, Usoh and Steed, 1994) we show that given the same sensory information from identical VEs different subjects process and respond to these in different ways. It is important to realise this in order to understand the true impact of external factors of the technology on individuals. As Steuer points out, "... virtual reality resides in an individual's consciousness; therefore, the relative contribution of each of these dimensions to creating a sense of environmental presence will vary across individuals" (Steuer, 1992).

In earlier work (Slater and Usoh, 1994; Slater, Usoh and Steed, 1994) we used a therapeutic and counselling technique known as neuro-linguistic programming (NLP) (Bandler and Grinder, 1975, 1979; Dilts et al., 1979; Lankton, 1979; DeLozier and Grinder, 1989) as a tool for understanding individual's responses to virtual environments. This is based on the two central ideas of *representation system* and *perceptual position.*

Briefly, the NLP model claims that subjective experience is encoded at a subconscious level in terms of three main representation systems; Visual (V), Auditory (A), and Kinesthetic (K). The visual channel includes external visual information and internally constructed images. The auditory channel includes external sounds and internal dialogue (such as talking to one's self). Similarly the kinesthetic channel includes tactile sensations and external forces exerted on the body, and internally derived feelings and emotions. Practitioners of NLP believe that an individual has a basic preference for one representation system over another. Therefore a person who is visually dominant would react more strongly to visual information and process external information through images, whereas one who is auditory would react highly to auditory data and process information through internally constructed sounds and dialogue. In previous experiments we attempted to determine the particular V, A, K representation system of the subject using pre-questionnaires (Slater and Usoh, 1994; Slater, Usoh and Steed, 1994). From these we collected and scored the number of V, A, K references made by the subject with the assumption that the more visual an individual, the more they would tend to use visual predicates in describing everyday reality. Such *a priori* knowledge may be utilised in a number of ways. Currently we use it in post experimental analysis. However, it also becomes possible to place individuals more evenly within experimental groups to filter out effects due to inadequacies of many VR systems. For example, since many systems present mainly visual data with little or no ambient aural information, differences between subjects may be minimised by streaming only those that are highly visual. Of course an accurate evaluation of a system as used by "real people" would require a cross-section of the population.

By perceptual position we mean the standpoint from which a person experiences or recalls a memory of an event. A person who is asked to recall an event, for example one that is somewhat traumatic, may do so from a position as seen from their perspective or location at the time of the event. This is known as an *associated* perspective, or from a *first* position. Alternatively, they may report the event from the perspective or location of another individual (*second* position), or from an abstract, non-personal viewpoint (*third* position). Therapists often employ knowledge of perceptual position during treatment of patients undergoing counselling. An event seen through a very personal, first position viewpoint ("I saw") is often more intense than one seen through a second position viewpoint ("He saw"), which in turn is more than a third position, abstract, non-personal viewpoint ("It was seen"). The relation between representation system and perceptual position is logically orthogonal as shown in Figure 1.

	Visual (V)	Auditory (A)	Kinesthetic (K)
First Position	I saw it...	I heard it...	I felt it...
Second Position	You saw it...	You heard it...	You felt it...
Third Position	It was seen...	It was heard...	It was felt...

Figure 1: Orthogonality of representation system to perceptual position

The different modalities of processing external stimuli are significant to virtual environments research since in order to understand how to create realistic and compelling worlds we must first of all understand the key components of the world which make it realistic and compelling for the participant. It may not be enough to engage a person by creating very complex environments which do not address the issues necessary for him/her to feel included in that environment - for example, a world which is visually detailed but lacking sounds or composed of inappropriate sounds being used by a person who is highly reliant on auditory cues.

In our work we do not take a standpoint in the validity of the varied claims of NLP but use the model as the basis for a method of investigation into the mode of perception of subjects immersed in virtual environments. Using NLP we have attempted to recognise and quantify this psychological state of mind or more accurately, the manifestations of the psychological state of presence (Slater, Usoh and Steed, 1995; Slater, Usoh and Steed, 1994). Other researchers have also noted its relevance to virtual environments (Pimentel and Teixiera, 1993).

5. Presence

Presence in a real or virtual environment is a psychological state of consciousness. It is a sense of "being there" in the environment which in the case of the virtual environment is displayed by a computer through appropriately connected hardware channels. Since immersion is a description of the technology of these channels, presence is therefore an emergent property of immersion. Thus immersion in an environment can lead to presence. It would therefore follow that features of a particular technology can influence the degree of presence of a person immersed in an environment determined by that technology. For example, a system which is able to track various parts of the physical body for mapping onto the virtual body in real time (without lag) is more likely to be presence inducing than one where lag (even in the order of milliseconds) exists (Barfield and Hendrix, 1995).

Although our computer system does not have tactile or force feedback gloves or devices for realisation of haptic data, the kinesthetic channel can still be stimulated by natural interactions in the environment. Since the subject can physically walk through the environment (although within the limitations of the tracking device and physical space), can bend down and look around by turning their head or body, and can pick things up by reaching out as in everyday reality, this maintains activity in the kinesthetic channel. Thus, an immersive environment is able to kinesthetically stimulate a participant by permitting them natural or "body centred interaction" within the environment without the need for direct stimulation devices.

We take the issue of presence as the central feature of virtual reality. This is realised by Steuer who writes: "A virtual reality is defined as a real or simulated environment in which a perceiver experiences telepresence" (Steuer, 1992). He uses telepresence in much the same way as we would use presence, the difference being that the former relates to a real physical environment and the latter to an artificially created one. For instance, an astronaut on earth whose actions are slaved to a robot working on Mars may experience telepresence if he is able to manipulate the viewpoint and limb responses of the robot through his own body-centred actions. This feeling of presence is what makes virtual reality unique from other forms of traditional human-computer interfaces. Although a flight stimulator also affords the user a sense of presence (within the cockpit), it is generally static in that it simulates the environment of a single aircraft model. A virtual reality system is, however, a general purpose presence transforming machine which can transform the human traveller through diverse environments.

It is important to note that although the greater the extensiveness of a system the greater the immersion, this does not always lead to greater presence between individuals. This is due to the endogenous factors which vary from person to person and determine how information is processed. There are three main components to this mental processing which are indicators of presence. They are:

(1) the subject's psychological sense of "being there" in the environment specified by the displays. This is an attempt to determine the overall psychological impact of the experience.

(2) the degree to which the VE, at times, became more of the reality than the external (real) world. Therefore, a high degree of presence in the VE should lead to the participant experiencing objects and processes in the virtual world as (temporarily) more the presenting reality than the real world in which the VE experience is actually embedded. A correlate of this is that the participant should exhibit behaviours that are the same as those they would carry out in similar circumstances in everyday reality.

(3) that recalling the VE experience should be more like recalling a visit to a place, rather than like describing images designating a place.

This third point is similar to the findings of Barfield and Weghorst who write, "...presence in a virtual environment necessitates a belief that the participant no longer inhabits the physical space but now occupies the computer generated virtual environment as a 'place' " (Barfield and Weghorst, 1993, p702).

5.1 Who needs presence?

Many people have in recent years labelled their applications as 'virtual reality'. Applications have been developed which claim to be virtual reality but offer no more than what was previously referred to as 3D interactive computer graphics (on a desktop screen). We take the standpoint that for an application to claim itself to be virtual reality it should have the potential to afford the user a sense of presence since this is the unique feature of VEs.

Although virtual reality offers naturalistic forms of interaction applicable for training, not all training procedures are applicable to virtual reality. In short, training does not necessarily require presence. This should be borne in mind when analysing results of VE experiments. As noted in (2) above a high degree of presence in a VE will cause the participant to behave in a manner similar to their behaviour in the real world under similar circumstances. This is what we would require if the VE was developed for the training of high speed skiers for example. We would want them to react to the virtual slopes, tilts, and turns as if they were real and to experience similar rushes of adrenaline as in the real world. In contrast, for teaching a person to type the most important factor is not for them to feel that the virtual typewriter was real and that they were actually sat in front of it. What is required in this case is a good user interface.

5.2 Relationship between presence and immersion

We have seen that presence is a function of immersion. It is also affected by the degree of proprioceptive feedback. We can illustrate this relationship in Figure 2.

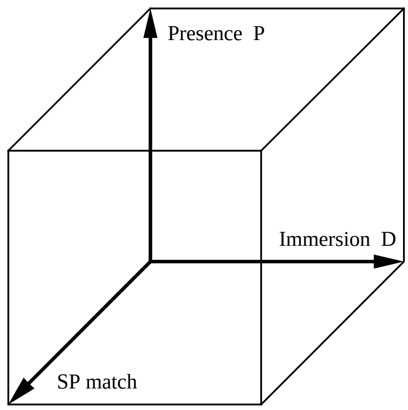

Figure 2: Influence of immersion and proprioceptive match on presence

From Figure 2 presence is a function of two parameters: immersion (D) and sensory/proprioceptive data match (SP). The immersion axis determines those external factors of the system as described in Section 4.1. For example, the greater the number of displays the greater the degree of immersion. The SP axis in turn determines the extent to which proprioceptive information received from the vestibular system coincides with the sensed data generated by the VE system. Presence is then given by

$$\text{Presence} = g(SP, f(D)) \quad (1)$$

where

$$f(D) = f_i(V_i, A_i, K_i, ...) \quad (2)$$

where f_i is a function of the displays relating to V, A, K for the individual i

The greater the match between sensory and proprioceptive data, the greater the potential for presence (Slater, Usoh and Steed, 1995).

6. Sensory/Proprioceptive match - An experimental study

We can investigate experimentally the relationship between presence and the sensory/proprioceptive data match (SP). We postulate that, other factors being equal, an increased match between sensory and proprioceptive information will result in a higher degree of presence.

Although immersive VEs allow participants to use natural body motions to interact and navigate, it is difficult to move across large distances due to limitations in the trackers and physical space. Many systems attempt to overcome this by allowing the participant to 'fly' within the ground plane by either pointing and making a hand gesture with a dataglove, or pressing a button on some form of interaction device. Direction of motion is governed by the direction the hand is pointing and velocity is usually constant. Although this form of interaction is simple - press the button when you want to move and release when you want to stop - subjects are sometimes confused that they are able to move through the environment by natural walking as well as by pressing a button on a 3D mouse (the interaction device). Another problem is that this does not engage the body in a manner similar to walking. A conflict arises between the body's proprioceptive information and the data received by the sensory organs. Optical flow indicates the effect of motion, yet proprioceptive information indicates that the person is standing still pressing a button which creates a proprioceptive/sensory data mismatch.

In experiments to test our hypothesis we devised a method of navigation which engaged natural body movements (Slater, Usoh and Steed, 1995). This resembled somewhat walking on a conveyor belt or treadmill and was called the *virtual treadmill*. More precisely the technique required the participant to "walk in place", i.e. on the spot. By monitoring data received from a sensor attached to the HMD the computer system is able to determine when the person was walking in place and when they were doing anything else, for example bending down or looking around. When they were walking in place it would move them in the direction of gaze within the VE. Velocity of movement was constant.

The advantage of the walking in place technique was that it was almost like real walking. It was body engaging and used motions similar to walking. The SP match would therefore be higher when compared with a technique based on pressing a button. In the experiment to test whether walking on the spot would result in an increased level of presence compared to hand navigation techniques we carried out an experimental case-control study. The experimental group were able to move through the virtual space by using the walking in place technique (walkers) and the control group moved by pointing and pressing a button on a 3D mouse (pointers). Each group contained eight subjects and had a functioning virtual body. The task in the experiment was to pick up an object located in a corridor, take it into a room an place it on a specified chair. The chair was located across a chasm over another room 5 metres below. The subjects had the option to move over the chasm (a direct path to the chair but involved walking on virtual air) or walk around a wide ledge around the edges of the room. This was an interpretation of Gibson’s visual cliff experiment (Gibson and Walk, 1960). The path taken by each subject to the chair was recorded as well as whether they hesitated or showed any physical reactions.

From post-experimental questionnaires subjective presence was assessed in three ways: the sense of "being there" in the VE, the degree to which the virtual experience was at times more of the engaging reality, and the extent to which the experience was like visiting a place rather than seeing pictures of a place. The subjects rated their experience using a series of questions on an ordinal 7-point scale. A sample is given in Table 1.

	Please rate
Please rate your sense of being there in the computer generated world.	1: not at all … 7: very much
To what extent were there times during the experience when the computer generated world became the “reality” for you, and you almost forgot about the “real world” outside?	1: at no time … 7: almost all of the time
When you think back about your experience, do you think of the computer generated world more as something that you saw, or more as somewhere that you visited?	1: something that I saw … 7: somewhere that I visited

Table 1: Sample of questionnaire of subjective presence

A multiple regression was used with a combined presence score as the response variable. Results showed that participants who strongly identified with the virtual body had a greater degree of reported presence if they moved through the environment using the walking technique than the pointing method. Here, association with the VB is an important factor indicating that it is not simply whether the system provides a VB, but the individual’s evaluation of it, that is the degree of "match" to their internal model. Also, the path taken to the chair was also an indicator of presence level - for those who chose the direct path their sense of presence was lower than those taking the "safe" option. However, there was no significantly observable indication of walkers preferring to use the safe route. This raises an interesting point - for those subjects reporting a high degree of presence but yet crossed the chasm, how did their behaviour in the VE resemble their behaviour in the real world? Did their level of adaptation or acclimatisation to the VE differ from those who had taken the safe path since they seemed to be exhibiting a behavioural mismatch?

7. Behavioural match and acclimatisation - An indicator of presence

Acclimatisation is the degree of familiarity and adaptation to an environment whether it is real or virtual. It is orthogonal to recognition and orientation such that the greater the sense of orientation or level of recognition, the greater the degree of acclimatisation.

We have noted that the greater the degree of presence for a person immersed in a VE, the higher the probability that their behaviour in the VE would be similar to their behaviour in the real world under similar conditions. We have also noted that the greater the level of immersion the greater the chances of a person experiencing presence in the VE. However, since immersion relates to the degree of information obtained from the displays, then greater immersion can also lead to a higher level of acclimatisation. This raises an interesting question - is there a relationship between presence and acclimatisation? In discussing this we pose two questions:

(1) Will people who are in a VE which they are familiar with in the real world behave differently from people who are not familiar with that environment?

(2) Is it possible for people who are not familiar with the environment to learn something about it from their virtual visit?

Regarding (1), it is important to be able to distinguish what "different" would be in terms of behaviour.

7.1 Experimental design and procedures

We modelled in VR a laboratory and some offices in the computer science department of UCL. This was accurately represented in terms of the colour and arrangement of desks, chairs, cabinets, and floor space. The laboratory was chosen because it was spacious and contained a large number of occupants - potential experimental subjects. These were PhD students and research workers of the department who were all well acquainted with the laboratory since it was their working environment. The laboratory was called Room 127 and we shall refer to the virtual model as V127. Being the computer science department each of the desks had a computer on it - also modelled in V127.

The experimental group consisted of occupants of Room 127 who had desks in the laboratory. The control group were taken from members of staff and students of the department who were not familiar with the room. Both groups consisted of 8 subjects. Each desk in the laboratory was assigned a number. Since the control group did not have desks in Room 127 they were randomly assigned a desk as "theirs". The factorial design is shown in Table 1, with 4 subjects per cell.

	Monochrome Environment	Realistic Environment
Experimental Group	Inhabited:4	Uninhabited:4
Control Group	Uninhabited:4	Inhabited:4

Table 1: Factorial design with number of subjects

The "realistic environment" was the V127 model with objects possessing correct colour and texturing information, and the "monochrome environment" had this information removed. An "inhabited" environment meant that 50% of the desks had a virtual person standing by them and "uninhabited" meant that there was no virtual person. The virtual people were "cardboard cut-outs" and were used to represent occupants of the laboratory.

Each subject was given a pre-experimental questionnaire regarding their representation system, and a post-experimental questionnaire regarding the virtual experience. They were given written instructions and a scenario which placed them in the context of the experiment and were observed throughout by the investigators. On entering V127 the subjects were given the opportunity to become familiar with the environment by moving through it - here navigation was performed by pointing and pressing a button. They were asked to indicate when they felt ready to start the experiment. At this point they would automatically move to the starting position and the investigators would cease to talk to them until the experiment had finished.

During the familiarisation phase, before the experiment began, subjects were told to observe the location of the virtual computers. So as not to influence their behaviour in the experiment by the wordings of the scenario, they were simply instructed to move through V127 and switch on 6 computers. They could switch on each one simply by touching it with their virtual hand and a picture would appear on its monitor. At this point they would automatically move back to the starting point. This makes the successive selections of computers statistically independent. The procedure was performed six times and at the end they were instructed to go back and touch the six computers they originally selected. This time after touching the computers they were not transported back to the starting position in order to test their spatial awareness. Had they acclimatised to the room or did they have to go back to the starting position each time?

After the virtual experience the subject was taken to the real Room 127 and the control group asked whether they recognised where they were. They were all asked to indicate on a map of 127 the location of the six computers they had selected during the virtual experience.

Indicators of presence in the experiment would be whether subjects maintained socially conditioned behaviours and conventions. If experiencing a high degree of presence an indication may be that the subject would not venture into an area occupied by a (virtual) person or private office. For the experimental group they would tend to switch on the computers which they were familiar with. We would expect these to include "their" computer and possibly those around their desk. To the control group V127 is completely strange and their pattern of behaviour should tend to be more random and not be significantly concentrated around the desk that had been assigned to them.

8. Discussion

In the experiment we attempted to determine differences in behaviour between the experimental group and the control group of subjects and the effect of different conditions on presence. We monitored their movements in the environment with the assumption that those who had a high sense of presence would retain socially conditioned behaviours.

The results showed no significant difference between the monochrome and "realistic" environment, nor between "inhabited" and "uninhabited". When comparing the monochrome and realistic environments it would appear that correct geometry is the most important factor over colour or texturing - no significant difference was found in the number of correct matches between computers selected in V127 and affirmed in Room 127. Surprisingly, there were also no immediate behavioural difference between the two groups. Activity within V127 seemed to be equally dispersed and not concentrated around a subject's "desk". In fact, they tended to be around the areas within a line of sight from the starting position. One experimental subject commented afterwards that he knew where "his" computer was but didn't select it because it was a long way away from the starting point.

As expected, however, the experimental group recognised V127 as being a virtual Room 127 on entering the scenario and the control group did not. However, the control group reported a higher subjective sense of presence. This may be because the experimental group "realised" what the experiment was about and made comparisons with the real Room 127 therefore not allowing themselves to accept the illusion. Statistical analysis did however reveal a relationship between group and auditory representation channel with associated presence. For the control group the level of presence decreases the more auditory the subject. For the experimental group there was no observable correlation. Also, the number of correct matches between the computers selected in V127 and those identified in Room 127 increases the more auditory the subject is, and decreases the more kinesthetic, independent of group.

9. Conclusion

In this paper we have given an account of virtual reality, a form of human-computer interface involving the immersion of the human participant into an extended space created by a computer system. We have discussed the concept of presence, a psychological sense of "being there" in the environment displayed by the computer. It is hypothesised that this increases with immersion and the level of match between sensed information generated by the computer system and the individual's world model.

We have argued that presence is the central issue in virtual environments and have attempted to identify and quantify it objectively. In previous work we have illustrated factors influencing a subject's degree of presence within the virtual environment and have shown how it may be enhanced by "grounding" the subject within the VE through a virtual body, and by increasing the match between proprioceptive and sensory data. In the work presented here we investigated the relationship between presence and acclimatisation using behavioural analysis. The results did not reveal a direct relationship but suggest that *a priori* knowledge of the real environment may, in some cases, cause subjects to evaluate the realism of the virtual environment. Also, they may realise partially, or think they realise the intentions of the experiment and behave in a manner different from "normal". In line with many experiments, this has raised more questions than it has answered. This, however, is what continues to drive the research.

In concluding we note that this work has been presented from a computer science viewpoint working within the area of psychology, rather than from a psychology viewpoint using computer science.

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