Immersive television



JONATHAN FREEMAN, JANE LESSITER *and* **WIJNAND IJSSELSTEIJN** *provide an introduction to 'presence' – a sense of being there – based on the research of the Immersive Television Project at Goldsmiths College.*

THE scene from the future opposite is imaginary, have no doubt; but the basic concept behind it is real. Psychologists are helping in the development of media systems that can generate a sense of presence in a remote environment. When an observer is presented with a high-fidelity representation of the physical world, a compelling perception of 'being in' the depicted scene is often elicited. It is this perception that is defined as presence: a sense of 'being there' in a displayed scene or environment (Barfield *et al.*, 1995). As presence increases, an observer becomes more aware of and engaged by the mediated environment, and less aware of the environment in which he or she is physically located (Freeman *et al.*, 1999).

Research into the psychology of presence has started relatively recently, as a result of technical developments that include improved video coding, the launch of digital TV, high-fidelity displays, improvements in human–computer interfaces and expanding computer processing power. Strong sensations of presence in users can be evoked both by advanced broadcast systems, such as high-definition, stereoscopic, and immersive TV (Lodge, 1999), and by virtual environments (VEs), which allow the interaction of human participants with an environment generated and displayed by a computer (Slater & Usoh, 1994).

Defining the determinants of presence, its structure, reliable measurement methodologies, and the effects of high-presence display systems on users are current focuses of the presence research community. This article provides a brief overview of current presence research that will help optimise the type of communication system described in our opening scenario.

Determinants of presence

Several factors that might determine users' presence have been suggested in the literature. Although terminology varies across authors, there is broad agreement on the major concepts. Based on various theoretical analyses, the factors thought to underlie presence include: the extent and fidelity of sensory information; the match between sensors and the display; content factors; and user characteristics.

Extent and fidelity of sensory information This is the amount of useful and salient sensory information presented in a consistent manner to the appropriate senses of the user. This includes Steuer's (1995) notion of 'vividness' – the ability of a technology to produce a sensorily rich mediated environment. Examples from this category include monocular and binocular cues to spatial layout, resolution, field of view, and spatial audio.

Match between sensors and the display This category refers to sensory-motor contingencies, that is, the mapping between a user's actions and the perceptible spatio-temporal effects of those actions. For example, using head tracking, a turn of a user's head should result in a corresponding real-time update of the visual and auditory display.

Content factors This is a broad category including the objects, actors and events represented by the medium, and the user's ability to interact with and modify the content of a mediated environment (Sheridan, 1992a, 1992b). Other content factors include the fidelity of the user's representation (or virtual body) in the VE (Slater & Usoh, 1994), and the autonomy of the environment, that is the extent to which objects and actors within the environment exhibit a range of autonomous behaviours (Zeltzer, 1992).

The nature of a user's potential activity and the meaningfulness of the content have also been suggested as potential determinants of presence. Further, it has been argued that content in terms of social elements, such as the acknowledgement of the user through the reactions of other actors, virtual or real, are important determinants of a related concept – social presence (Heeter, 1992). Measures of social presence are likely to be particularly useful in the development of shared VEs, where communication efficacy is a key goal (e.g. Towell & Towell, 1997).

User characteristics These are also likely to play a significant role in users' sensations of presence, but to date have received little attention. Such characteristics include a user's perceptual, cognitive and motor abilities (e.g. stereoscopic acuity, susceptibility to motion sickness, concentration), prior experience with and expectations towards mediated experiences, mood state, and personality (in particular, related to a willingness to suspend disbelief).

Relevant individual characteristics are likely to vary with the age, and possibly with the sex, of the user. Huang and Alessi (1999) point out that various mental health conditions, such as depression, anxiety, or psychotic disorders, are also likely to affect an individual's sense of presence, since they affect individuals' experiences of the world around them. Indeed, as presence is a transient experiential state (Sheridan, 1992a, 1992b), like mood, it is susceptible to variation within the same person, given the same physical conditions, on two separate occasions.

Attending to the mediated environment

WEBLINKS

The following websites give further information on presence research and on the Immersive Television Project:

homepages.gold.ac.uk/immediate/immersivetv/

www.presence-research.org/

and, relatedly, attenuating attention to the physical environment have also been proposed as important determinants of presence (e.g. Draper *et al.*, 1998; Witmer & Singer, 1998). The proposed role of allocation of attention in determining presence suggests that presence is not an all-or-nothing phenomenon (cf. Schloerb, 1995) but a graded experience.

The first two groups of determinants above are best described as media form variables, capable of making the medium non-intrusive such that users are not aware of it and thereby creating a 'perceptual illusion of non-mediation'(Lombard & Ditton, 1997). To create and sustain this illusion, distractions and negative cues to presence should be avoided. For example, an awkward user interface is likely to stress the mediated nature of a media experience and consequently reduce users'presence. Examples of such negative cues include bad stereoscopic alignment (causing eye strain), video distortions (causing visible 'blockiness' or noise), the weight of a head-mounted display, process interruptions (e.g. 'new mail' notifications or system malfunctions), noticeable tracking lags, low update rates, and stereo occlusion conflicts.

Further, the attentional resource model of presence of Draper *et al*. (1998) predicts that distractions which draw the user's attention away from the mediated environment to the physical environment, such as a telephone ringing in the user's physical environment, are also likely to lower the user's sense of presence. Certain common broadcast conventions, such as an identification logo appearing in the comer of the screen, may also reduce a user's illusion of non-mediation (Lombard & Ditton, 1997).

A SCENE FROM THE FUTURE

It is 7pm on Wednesday 28 May 2031. You've been looking forward to this evening for the last two months, ever since you finally got around to upgrading your home Immerse-U-There© Technologies communication system as a birthday treat.

You've noticed some real benefits since your system upgrade. The early days of teleworking using a home PC and a modem seem so primitive now, just 20 years after it became the *modus operandi* for the majority of the world's working population. Gone are the days of hoping that your voice communicated the right degree of warmth down the ether to your colleagues (the rudimentary video communications of the early 21st century didn't allow you to feel like you were really having a face-to-face meeting with your clients and colleagues).

Just like the real thing?

Today you had a group meeting on the global communication strategy of the natural drinks company you work for. At the meeting was Jaap, the company's head communications strategist, joining direct from his village just outside Eindhoven. Shigoro, head of marketing for Asia, has just moved to a self-sustaining village just outside Tokyo, but that didn't stop him attending. Judy and Lorraine (heads of marketing communications in North and South America respectively) were in the middle of a trek through the Borneo jungle but were able to join in too using their portable Immerse-U-There© systems. And finally, Maxine was there. Maxine is your old-timer boss, now in her late nineties, who was resolutely against 'new technologies' changing her work practices until she realised that her new Immerse-U-There© system could keep notes on everything that everyone said in the meeting, generate automatic contact reports and enable her to more or less take up residence at her local golf course.

It was a constructive meeting all round. Got a bit heated when the ad agency tried to pretend their Immerse-U-There© system was broken as an excuse for joining the meeting late. You've heard that excuse from the agency at least 12 times this year – and you know its been a lie each time. Anyway, the agency came up with the goods just in time. The meeting went on for three hours – lucky really because that is the safe continuous use limit set down by the Global Standards Commission. At 2pm (World Standard Time) everyone tuned out after a hard day's work – your children still don't believe you when you tell them that only 10 to 15 years ago people were working 50 plus hours a week, and that there were different time zones around the world!

You're excited, because in about half an hour you'll be in Rio de Janeiro for the 2031 World Club Championship Final. Tickets for seats in the ground sold out over 10 years ago, but with your new Immerse-U-There© system you literally feel as though you are there. You've got the best seat in the stadium, the smells of Brazil, you can feel the atmosphere (it's hot and humid there tonight), you can hear every little whistle or quip that you'd hear if you were really there (and you will even be buzzed – but not bitten – by the local mosquitoes). There's no need to fly: as a result of the Immerse-U-There© systems becoming the world communication standard (in 2022), you haven't had to fly anywhere for seven years. And best of all, you can sit and watch with your remote friends around the world. Your kids might join you for parts of the game, but they spend most of their free time these days watching earth from the Global Space Station (through their personal Immerse-U-There© systems).

You settle back to enjoy the game. And you have to hand it to the system developers,they knew what they were doing. You really do feel like you're in Rio, with your friends. And it really does feel worth it.

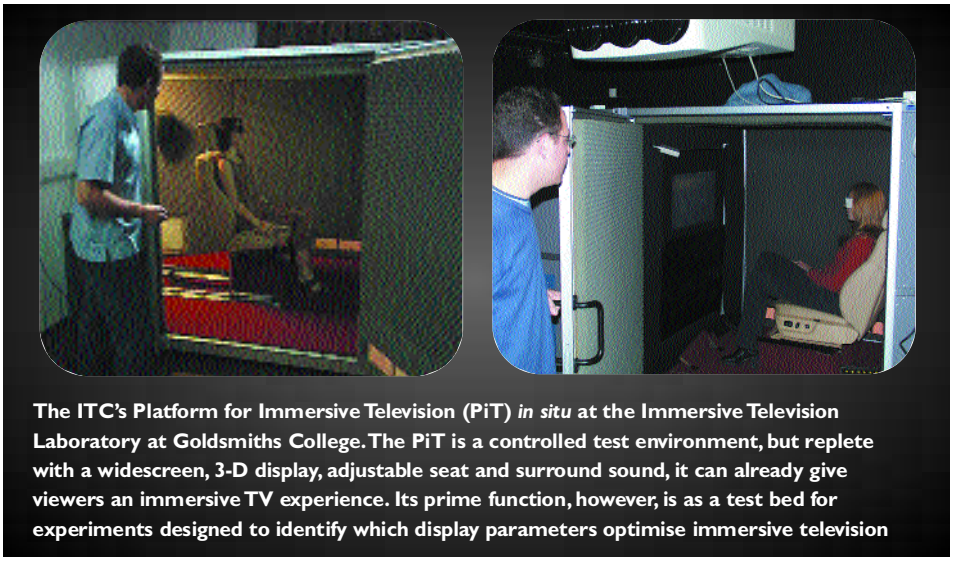
Measuring presence by questionnaire

Presence has been evaluated primarily using self-report questionnaires, until recently using between one and three simple post-test rating scales. These rating scales have required judgements comparing either the mediated experience to real life (Hendrix & Barfield, 1996; Slater & Usoh, 1994) or to another mediated environment (via paired comparisons, e.g. Welch *et al*., 1996).

Typically, the rating scales have consisted of statements relating to the extent to which individuals (a) feel physically located in a given mediated space, (b) sense that the mediated environment is as real as the real world, and (c) feel that the mediated space is more than merely a mediated multisensory presentation, like somewhere they have 'visited'. These questions attempt to capture the essence of presence, and have been shown to be sensitive to manipulations of display parameters (e.g. field of view: Hendrix & Barfield, 1996; stereoscopic presentation: Freeman *et al*., 1999; interactivity: Welch *et al*., 1996). However, Freeman *et al.* (1999) provide evidence suggesting that simple presence ratings can be affected by prior experience and are thus potentially unstable. In addition, the 3-item presence scales do not take account of the potential multidimensional nature of presence described below.

More detailed questionnaires have been developed both to elucidate the presence construct and to provide a more reliable and valid index of its dimension(s). Four recent studies have applied data-reduction statistical techniques to their questionnaire data to refine their presence measures and to explore the construct.

Witmer and Singer (1998) performed



The ITC's Platform for Immersive Television (PiT) *in situ* at the Immersive Television Laboratory at Goldsmiths College. The PiT is a controlled test environment, but replete with a widescreen, 3-D display, adjustable seat and surround sound, it can already give viewers an immersive TV experience. Its prime function, however, is as a test bed for experiments designed to identify which display parameters optimise immersive television

a cluster analysis of 152 participants' responses to a 32-item post-test presence questionnaire enquiring about an interactive VE experience. They identified three clusters: (i) participants' sense of involvement in and control over the VE experience; (ii) participants' sense of the naturalness of interaction and locomotion within the VE; and (iii) participants' perceptions of the quality of the VE interface (in terms of intrusiveness and distractability).

In a factor analysis of 246 (90 per cent male) computer games players' responses to a 75-item questionnaire, Schubert *et al.* (1999) identified distinct 'presence'and 'immersion' factors. Immersion was characterised by factors relating to the quality of the interface (the objective physical properties of the mediated environment, e.g. the number of senses stimulated by a media system). Presence involved factors of spatial presence (a subjective sense of being within a physical space depicted by the media), involvement, and the realness of the VE compared to the real world.

Kim and Biocca (1997) administered a short 8-item questionnaire to 96 people exposed to NTSC (US standard) video displays. They reported two factors in observers' responses: presence as 'arrival' (a sense of being present in the mediated environment), and presence as 'departure' (a lack of awareness of the physical world). Interestingly, they noted that the two factors were independent of each other. This is consistent with the assertion of Draper *et al.* (1998) that presence can be viewed as an allocation of attentional resources.

There are several limitations to these studies and their respective questionnaires, relating to sampling and to question content. First, each of the studies was based on restricted and sometimes small samples (e.g. computer games players or VE users) limiting their generalisability to other groups. Furthermore, Slater (1999) takes issue with Witmer and Singer's questionnaire on the grounds that some of its items address objective, physical properties of the technology as well as subjective aspects of the media experience – thereby confounding the two. In addition, the questionnaires used in each of the studies were tailored to specific media.

Lessiter *et al.* (2000) developed a 63-item questionnaire (the ITC Sense of Presence Inventory) that has been administered to over 600 respondents after an experience with one of a range of media – including IMAX 2-D and 3-D presentations, standard cinema, interactive computer games, and standard broadcast quality television – displaying varied content.

Factor analysis of the initial dataset revealed four factors: (i) a sense of being physically located within the media space, which includes items relating to interactivity ('sense of physical space'); (ii) a sense of involvement with the narrative unfolding within the media space ('engagement'); (iii) a sense of the naturalness of the mediated occurrences or content ('ecological validity'); and (iv) 'negative effects' – providing a measure of the adverse effects of prolonged exposure to immersive media.

The four factors had high intemal reliability. To assess validity, scale means for the first factor ('sense of physical space') were compared across the media formats (see Figure 1). Despite variation in the actual content of what was shown, presence scores increased with enhancement of the media form (both in terms of the extent and fidelity of sensory information (visual and auditory) that the media provide, and with users' ability to interact with the environment).

The factor structure obtained by Lessiter *et al.* is very similar to that reported by Schubert *et al.* (1999), but was obtained from a sample that had experienced a range of interactive and non-interactive media – thereby adding to its generalisability. Whilst the first factor to emerge from factor analysis of Lessiter *et al.* best matches the standard definition of presence, the four factors may be interrelated. A revised 44-item version of the ITC Sense of Presence Inventory is now being used, and confirmatory factor analyses are planned with new samples, including users of fully immersive VEs.

Behavioural realism

The 'behavioural realism' approach has been advocated as an objective means of corroborating subjective presence ratings (Freeman *et al.*, 2000). Behavioural realism is based on the premise that as a display system better approximates the environment it represents, users' responses will tend to those which they would exhibit to the environment itself. Variants of the idea have been proposed several times in the literature (e.g. Held & Durlach, 1992; Sheridan, 1992a).

Freeman *et al.* (2000) investigated the utility of postural responses as estimates of presence. Postural responses were selected because they are reflexive actions, of which participants are not normally aware. Participants' postural responses were measured using a magnetic position tracker as they stood viewing a video of a rally car traversing a bending track at speed. The video stimuli were filmed using miniature cameras positioned on the bonnet of the car.

Stereoscopic (3-D) video presentations produced significantly larger postural responses than did monoscopic presentations (2-D). Simple post-test ratings of presence, vection (sense of self-motion) and involvement were also significantly higher for the stereoscopic presentations of the stimuli, but were not significantly correlated with participants' postural responses.

The absence of a correlation between

the subjective and objective measures suggests that postural responses cannot be taken as direct substitutes for subjective presence ratings, although they may still offer utility in the evaluation of display parameter manipulations and in the corroboration of subjective presence findings. Clearly the postural response measure is highly content dependent, in that it is suitable only for stimuli containing motion. The issue of content-dependency makes the development of a general behavioural presence metric unlikely.

Psychophysiological techniques

The principle underlying the use of physiological measures for the assessment of mediated environments is similar to that of the behavioural realism approach. In effect, as a display system better approximates the environment it represents, so users' physiological responses will tend to those which they would exhibit to the environment itself. As with the postural response measure discussed above, participants are unlikely to be able to modify their automatic, physiological responses.

Two physiological indices have received particular attention in the presence literature: electrodermal activity (EDA) and cardiovascular activity.

EDA has been associated with emotional arousal. For example, Bernstein (1969) reported that as stimulus intensity increases so does EDA. In addition, relationships between EDA and memory have been reported in the literature (see review by Revelle & Loftus, 1992).

Changes in cardiac activity are not indicative of one type of behaviour, though specific psychological functions have been linked to patterns of cardiac activity. For example, as the intensity of an emotional experience increases, so does heart rate. Further, positive emotions are associated with greater ECG activity than negative emotions, thus heart-rate is sensitive to hedonic valence (Lang *et al*., 1993). Also, in reaction to unexpected stimuli, heart-rate decelerations have been associated with the orienting response to novelty, and accelerations with defensive responses, such as fear and anxiety (Graham, 1992).

Moving images produce higher levels of EDA and larger heart rate decelerations, whilst elevating subjective ratings of emotional intensity (e.g. Detenber *et al.*, 1998). Similar results have been reported with manipulations of display screen size (Lombard *et al*., 2000). Furthermore, preliminary data from the ITC Immersive TV laboratory (see below) also suggest that physiological responses are sensitive to manipulations of media form (2-D vs. 3-D) and content (see Dillon *et al*., 2000). Dillon *et al*. report that stereoscopic video presentation results in increased arousal relative to monoscopic presentation.

However, other studies have found no relationships between presence and physiological arousal (e.g. Weiderhold *et al.*, 1998). Nevertheless, the relationships between subjective measures of presence and arousal, and physiological responses to mediated environments have yet to be systematically investigated. The results of the majority of studies that have investigated the issue suggest that physiological measures are worthy of pursuit in presence research.

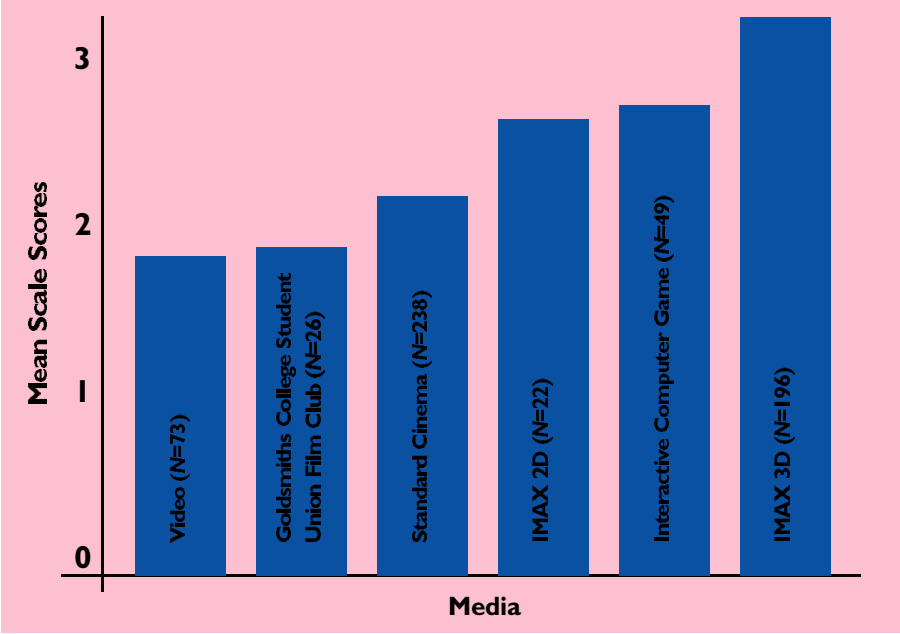
The Immersive Television Project

The Department of Psychology at Goldsmiths College has been awarded a substantial research contract by the UK Independent Television Commission (ITC). The 3-year project is investigating experiential aspects of viewing immersive television – TV that can engender in viewers a sense of presence at live events. As in our imagined opening scenario, immersive television (or your Immerse-U-There© personal communication system!) may be used for the broadcast of football matches, theatrical productions or concerts for which demand for tickets often outstrips supply. This suggests a market for broadcast presentations of such events that provide the viewer with more sensory information than traditional TV presentations deliver, thereby more accurately reproducing the experience of being there.

Psychologists are involved in the design and development of advanced broadcast services because the ITC recognises that the success or failure of such services will depend on how satisfying is the viewing experience they provide. Digital TV was launched in late 1998 in the UK, providing the capacity for innovative broadcast services. Whilst immersive, interactive and 3-D broadcast experiences may be the norm in 10, 20 or 30 years time, technology developers need to know how this new type of service can be optimised.

Measures of arousal, interest, attention, and presence will assist in determining the most cost-effective way of delivering immersive broadcast experiences. The potential adverse effects of immersive experiences, such as eyestrain, headache and nausea, are also pertinent issues (especially for regulators of future media services, such as our fictional Global Standards Commission). Other avenues for

FIGURE 1 Graph showing mean scale scores for 'sense of physical space' factor of ITC-SOPI for different media types. Content was varied but the order of the 'sense of physical space' scale means was as predicted from the presence literature



research that may form part of the project include individual differences in tendencies to feel present: what makes some people more susceptible to presence than others?

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