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Elements of a multi-level theory of presence: Phenomenology, mental processing and neural correlates

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Summary

Presence research is still at an early stage of development, and theoretical contributions are needed that integrate diverse insights relevant to understanding presence, emerging from different contributing areas. In this paper, we outline what we regard to be key elements of a theory of presence, addressing the experience at three distinct levels of explanation: phenomenology, mental processing, and underlying brain mechanisms.

Keywords: presence theory, 3D space perception, attention, neural correlates

1. Introduction

In a sense, all reality is virtual. It is constructed through our sense organs and cognitive apparatus. Reality is not "out there", it is what we take to be "out there". The brain is tuned in a sophisticated way to the perceptual invariants of our physical environment. Using these invariants, one can also produce illusions which the brain will be unable to discriminate from physical reality. This is the basis of various visual illusions, sleight of hand, and, more recently, virtual reality.

Presence, the experience of ‘being there’ in a mediated environment, has become closely associated with VR and other advanced media. As media become increasingly interactive, perceptually realistic, and immersive, the experience of presence becomes more convincing. However, it is interesting to note that we can feel present, and will respond accordingly in terms of behaviour, in mediated environments which clearly will not be mistaken for reality if we were to be asked. Even the impoverished world that VR provides appears to be sufficient for a perception of ‘being in’ the computer-generated environment. When considering the minimal cues provided by VR to our perceptual apparatus, it becomes clear that the experience is not governed solely by bottom-up sensory input, but that appropriate top-down knowledge interacts with these input signals to construct an *apparently* coherent and complete mental representation of space. As with the so-called ‘real world’, the experience of a complete and vivid virtual world, continuous in space and time, is an illusion based on the opportunistic, economical, and top-down nature of our visual system (Dennett, 1991; Stark, 1995; Gregory, 1998; Hoffman, 1998; Levin & Simons, 2000).

2. Levels of explanation

With the advent and improvement of perceptually realistic, immersive, interactive and engaging media, the experience of presence has become an area of scientific inquiry that has the potential to bridge the gap between media and minds. To do so, research is needed that connects insights from relevant technologically oriented domains, such as computer science and display development, with relevant knowledge from sociological, psychological, and neuroscientific domains. A theory of presence is needed that builds on insights from these diverse areas, has explanatory power, and can usefully predict the effectiveness with which various media technologies may elicit, enhance or maintain desirable levels of presence. Such a theory of presence has yet to emerge, but first steps in this direction have been taken (e.g. Draper, Kaber & Usher, 1998; Slater, 2001). In this paper, we will attempt to outline key elements of a theory of presence, addressing the experience at three distinct levels of explanation - *phenomenology*, *mental processing*, and *underlying brain mechanisms*. All three levels are necessary for an understanding of what is going on when people experience a sense of 'being there'. The term 'phenomenology' is used here to denote the subjective experience, including the contributing dimensions or correlates of presence. One drawback of attending *only* to a phenomenological level is that it limits models to mere description and classification, rather than addressing the explanatory 'why' and 'how' questions needed for true understanding of a phenomenon. These questions are addressed when exploring the mental and neural *processes* that may underlie presence.

3. The phenomenology of presence

As a user experience, the feeling of 'being there' is not intrinsically bound to any specific type of technology – it is a product of the mind. In normal, daily life we are seldomly aware of our sense of presence in the world. It is not an experience we are used to reflecting upon. As conscious and awake perceivers we have little doubt of the visible three-dimensional world which extends in front of us, and that we are part of this space.

If we want to understand presence as it relates to media, we will need a thorough understanding of the human perceptual experience in real environments. When comparing real space to virtual space, limiting ourselves to visual media for the time being, we find that real world perception has several critical features (Avons, 1996):

- Static depth information is provided via several independent mechanisms (e.g. linear perspective, interposition, texture density gradients, binocular disparity) that are consistent with each other and the observer's viewpoint.
- The resolution and intensity of the image is only limited by the sensitivities of our visual system.
- The effective image size fills our entire field of view, limited only by our facial structures, but without an externally imposed frame.
- Dynamic depth information (i.e. motion parallax) is coupled to observer movement

As we move towards increasingly realistic media, each development in visual media can be viewed as a gradual build-up of perceptual cues that simulate natural perception and enhance the experience of presence (Biocca, Kim & Levy, 1995). Early perspective paintings, dating back to the middle ages, only included static monocular depth information which violated most of the critical features of real-world perception mentioned above. The end of the 18th century saw the introduction of panorama paintings, which stimulated large portions of the visual periphery, a principle that was also applied to great effect in the cinema of the 1950s (e.g. Cinerama, CinemaScope), and in more recent large film formats (e.g. Imax, Omnimax). The stereoscope of the 19th century allowed each eye to view the same scene from a slightly different perspective (i.e. stereoscopically), contributing greatly to the perception of egocentric distance and exocentric depth within an image.

With the introduction of cinema, motion has been added to high-resolution photorealistic imagery as a fundamental perceptual cue. The visual system is highly motion-sensitive, and the onset of motion cannot be ignored - it demands attention (Reeves, Thorson, Rothschild, McDonald, Hirsch, & Goldstein, 1985) and automatically elicits an orienting response. Certain camera movements provide motion parallax as a cue to depth, although it is important to note that observer movement does not transform the image appropriately. In the case of head-mounted virtual environments this viewpoint-dependent transformation is possible in real-time, although with the current state of technology real-time interactivity trades off against photorealism.[1] Importantly, it is not clear at present how much each feature or perceptual cue contributes to the perceived realism of media, or to eliciting a sense of presence for the participant, nor is it clear how these cues interact with each other.

Although some authors argue strongly for a realism-based conception of presence (e.g. Solomon, 2002), this limits presence (at least with the current state of technology) to a mainly passive perception. The approach taken in VR is clearly based on interaction, yet with a usually low level of perceptual realism (high-end flight simulation systems perhaps being the exception). It is interesting to note that both non-interactive, photorealistic displays, as well as interactive, non-realistic displays are able to engender substantial levels of presence, where interactivity appears to be the more important factor of the two. It is of clear theoretical and practical value to establish what the optimal mix of cues might be for different application contexts, or, if the optimum is unattainable, which elements are most critical to the experience of presence. As Heeter (1992) noted, "the alchemy of presence in VR is in part a science of tradeoffs". Ellis (1996) has argued that an equation relating presence to its contributing factors should allow for iso-presence equivalence classes to be established, i.e. maintaining the same level of measured presence, whilst trading off contributing factors against each other.

Two general categories of variables can determine a user's presence: (i) media characteristics, and (ii) user characteristics. This differentiation is in line with the distinction made by Slater and colleagues' (e.g. Slater & Wilbur, 1997) between "external" (objective) and "internal" (subjective) determinants of presence. Characteristics of the medium can be subdivided into media *form* and media *content* variables. Both of these are known to have a significant impact on

[1] At the time of this writing, the computational resources that photorealistic real-time graphics rendering require are still too demanding for current systems. Significant simplifications need to be incorporated in the virtual world models in order to make them run interactively in real-time without perceptible lags.

the individual's sense of presence such that, depending on the levels of appropriate, rich, consistent, and captivating sensory stimulation, varying levels of presence can be produced.

Sheridan (1992) proposed three categories of determinants of presence: (i) the extent of sensory information presented to the participant, (ii) the level of control the participant has over the various sensor mechanisms and (iii) the participant's ability to modify the environment. These three factors all refer to the media form, that is, to the physical, objective properties of a display medium. Additionally, the media content is of vital importance. The objects, actors, and environments represented by the medium, often tied together in a logical flow of events known as the narrative or story, are essential in keeping the user interested and involved. Social elements, such as the reactions of other actors, virtual or real, to the user's presence in a mediated environment provide an acknowledgement to the user that signals the reality of his or her existence in virtual space.

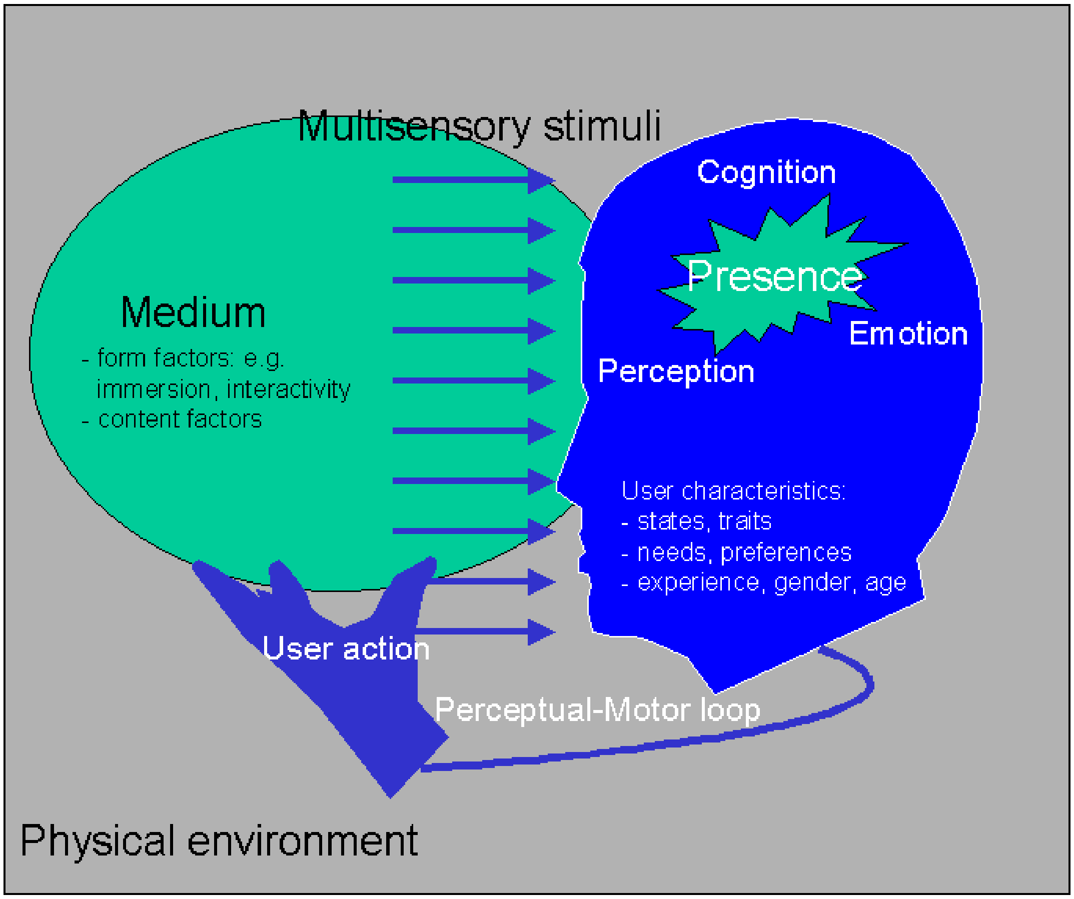
As a product of the individual's mind, it is highly likely that the presence experience will vary significantly across individuals, based on differences in perceptual-motor abilities, mental states, traits, needs, preferences, experience, etc. For a more detailed overview of presence determinants, see e.g. Lombard & Ditton (1997), IJsselsteijn, de Ridder, Freeman, and Avons (2000) or Sadowski and Stanney (2002).

Although most subjective presence measures (i.e. self-report questionnaires) seem to assume that presence is a static long-term internal state, presence appears to be an experience that varies in a moment-to-moment fashion (Heeter, 2001). IJsselsteijn, de Ridder, Hamberg, Bouwhuis & Freeman (1998) found that the reported level of presence varies considerably over time depending on the displayed content and the extent of sensory information available in the stimulus material.

Factor analytic studies are starting to shed light on the multidimensional structure of presence. In particular, studies by Schubert, Friedman, and Regenbrecht (1999) and Lessiter, Freeman, Keogh, and Davidoff (2000) reveal very similar factor structures. Schubert et al. (1999) arrived at a 3-factor solution for the presence construct, which they termed 'spatial presence', 'involvement', and 'realness'. Similarly, Lessiter et al. (2000) reported a 4-factor solution for presence, with three factors almost identical to the ones identified by Schubert et al.: 'physical space', 'engagement', and 'naturalness', and a fourth attenuating factor they termed 'negative effects'. Importantly, both Schubert's 'involvement' factor and Lessiter's 'engagement' factor point at a central role for attentional mechanisms in engendering a sense of presence.

4. Perception and action in 3D space

In the figure below, we have summarised the main factors that are likely to play a role in determining the presence experience. In this diagram, the continuous perceptual-motor loop reflects the ongoing process of real-time action-based perception, i.e. perception that changes dynamically as we move through and interact with the world in real-time. Although action is symbolised by a hand in the figure, other actions, including eye, head and body movements are of



obvious importance as well. Perception is not regarded here as passive template-matching. Rather, it is a highly activity-dependent and context-dependent process (both embodied and environmentally and temporally embedded) that integrates multimodal sensory data, ongoing actions and intentions, and cognitive and emotional processes.

The way the world responds to our actions can be conceived of as a *reality test*. If the world transforms in a way that is consistent with our perceptual representations of the invariants of the physical environment, for example exhibiting appropriate motion parallax as we move our heads, we are more likely to accept the world at face value. The term ‘representations’ in this case does not necessarily refer to stored symbolic representations, such as attributes, prototypes, or schemata, but also to perceptual-motor knowledge that is highly embodied, decentralised, and context-dependent[2].

In general, the space that surrounds the user can be meaningfully segmented into a number of ranges, usually three or four, based on principles of human perception and action. Several models have been proposed (e.g. Grusser, 1983; Rizzolatti & Camarda, 1985; Cutting & Vishton, 1995), all of which distinguish between a *peripersonal space* (the immediate behavioural space surrounding the person) and a far or *extrapersonal space*. For instance, Cutting and Vishton (1995) divided the spatial layout surrounding the perceiver into three egocentric regions that grade into one another: personal space, action space and vista space. *Personal space* refers to the zone that falls within arm's reach of the observer, thus having a diameter of around 2 meters. Beyond the range of personal space, *action space* refers to the space of an individual's public actions. Within this space we can move quickly, speak easily and toss or throw objects. Cutting and Vishton (1995) suggest this space is limited to about 30m on the basis of the decline in effectiveness of disparity and motion perspective as cues to spatial layout. Beyond this range, *vista space* stretches out until the visual horizon.

In a synthesis of various different 3-D spatial interaction models, Previc (1998) arrives at a model describing 4 different behavioural realms in 3D spatial interaction: (i) peripersonal, (ii) focal extrapersonal (the dynamic space of visual search), (iii) action extrapersonal (for navigation and target orientation), and (iv) ambient extrapersonal (for spatial orientation and a stable perception of the world serving postural control and locomotion). Previc (1998) presents a detailed account of the functional, neuroanatomical, and neurochemical bases for such a division of behavioural space, as well as its implications for neuropsychology. Based on such a differentiation in human 3D space perception, Subramanian & IJsselsteijn (2000) have proposed a classification of 3D interaction devices, dividing them into tablet-size, tabletop-size, and room-size interaction devices. It was noted that the larger range of spatial feedback, corresponding to the ambient extrapersonal space, created spatial overview and atmosphere, thus being of particular importance to presence.

Perception serves the individual's need to control relevant moment-to-moment behaviour or action within a changing environment. The strong coupling between perception and action has its basis in the *ecological approach* to perception, owing much to the thinking of James Gibson (1966; 1979). The term 'ecological' refers to the emphasis this approach places on the relationship between the individual and his or her environment. From this perspective, the combined characteristics of the environment and the individual define what is possible for the individual within the environment. In Gibson's terminology, the environment is perceived by the individual as a set of *affordances*, i.e. 'the actions a given environment affords to a given acting observer'. Thus, in the ecological approach, perception and action are tightly interlocked and mutually constraining phenomena. In support of this view, the neural basis of object and space perception provides evidence that sensory and motor representations are closely tied together. Our

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[2] More specifically, self-contained behaviour-producing subsystems that respond directly to specific properties of the environment without an overall plan or central executive system may alleviate the need for using elaborate symbolic representations in movement control. Local perceptual-motor feedback loops are needed to generate real-time behavioural responses that are adaptive and robust to rapidly changing environments, which often do not allow for the processing time needed to perform central executive planning of motor action (see e.g. Clark, 1996).

peripersonal visual space appears to be represented to a large extent in terms of movement-based space, i.e. space in which objects are reachable or graspable (e.g. Rizzolatti, Fadiga, Fogassi & Gallese, 1997). On the other hand, taken to its extreme, the direct sensorimotor correspondence argued for in the ecological approach fails to capture some important aspects of the psychological control of action, most notably the role of intentions, goals and motor planning. In addition, the emphasis on direct specification of action parameters from visual parameters without any intermediate representations disregards the issue of potential transformations of sensory information to make it relevant to motor control. Perhaps a synthesis of both cognitive and ecological approaches to 3D space perception is called for, thus arriving at a representation of the underlying spatial layout of an environment, as well as the affordances of such a layout. As Sedgwick (2001) has noted, neither of the alternative views has yet developed a compelling argument for its exclusive validity.

What does all this tell us about presence? As mediated environments allow real-time action at a distance (through teleoperation) or in virtual space, the participant is able to control certain aspects of the environment, and, as a consequence, his or her perception of the environment. In this way, the participant will become aware that he or she is an *actor* within the environment and it is likely that this experience of wilful control or *feeling of doing* will greatly enhance the feeling of being there within the mediated environment – the sense of presence. This view of active perception within real and interactive mediated environments is in line with the views expressed by Zahorik and Jenison (1998) and Flach and Holden (1998). Based on ideas of Gibson and Heidegger, Zahorik and Jenison (1998) conceptualised presence as tantamount to successfully supported *action* in the environment. *Being there* thus becomes the ability to *do there*. This conception of presence seems to place a clear emphasis on interaction in the peripersonal space, the space in which sensory and motor systems act in unison to grasp and manipulate objects. However, it seems very likely that the space beyond where our actions can exert immediate control over the environment, i.e. the extrapersonal space, will be of high importance as well to establishing a sense of presence in the environment. For instance, ambient extrapersonal space plays a crucial role in spatial orientation, postural control, and locomotion, which underlines its importance for establishing a sense of 'being' relative to the current environment. Thus, notwithstanding the importance of the ability to perform actions in a mediated environment, it should be noted that there is also considerable value in the concept of presence as it relates to non-interactive media, as space perception can only be partially based on action.

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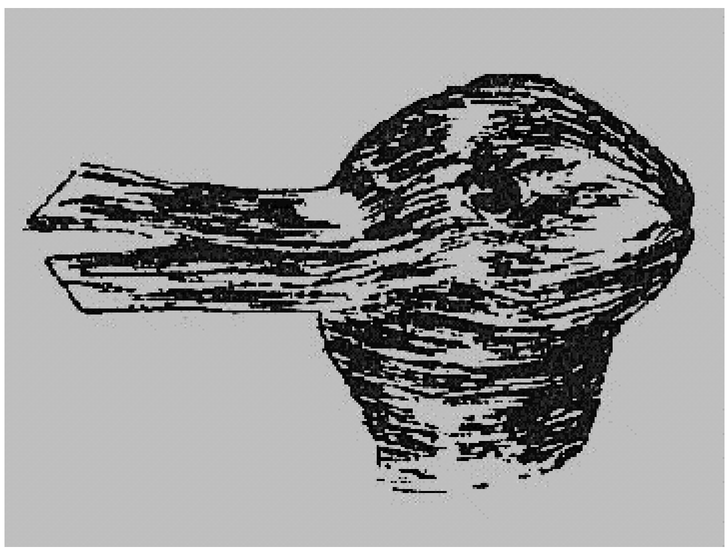
5. Attention and hypothesis selection

Multisensory stimulation arises from both the physical environment as well as the mediated environment. Importantly, there is no intrinsic difference in stimuli arising from the medium or from the real world – the fact that we can feel present in either one or the other depends on what becomes the dominant perception at any one time. Both bottom-up and top-down processes will play a significant role in determining this – presence in a mediated environment will be enhanced when the environment is immersive and perceptually salient, as well as when attentional selection processes are directed towards the mediated environment, thus allowing the formation of a consistent environmental representation (Slater & Steed, 2000; Slater, 2001). Draper et al. (1998) describe how both the computer-mediated world and the local environment may compete for limited attentional resources. Telepresence occurs when more attentional resources are allocated to the computer-mediated environment: “The more attentional resources that a user devotes to stimuli presented by the displays, the greater the identification with the computer-mediated environment and the stronger the sense of telepresence” (p.366).



A slightly different approach is taken by Slater (2001) who, based on the work of Richard Gregory and Lawrence Stark, describes the notion of presence as a perceptual mechanism for organising the incoming stream of sensory data into a coherent environmental Gestalt, essentially selecting between alternative hypotheses of self-location: ‘I am in this place’ versus ‘I am in that place’. Slater claims that the issue of presence is only interesting when there are competing signals from at least two environments.[3] Of course, any mediated environment is always embedded within a real world setting, thus providing an alternative environment by definition. One implication of presence as a Gestalt-switch is that it becomes an all-or-none phenomenon.

[3] This view of presence appears to resolve one of the ongoing discussions in the presence community, i.e. whether the concept of presence should be reserved for mediated experiences only, or whether it should be applied to unmediated “real world” experiences as well. Presence appears to be the ‘default’ experience in any environment where no cues exist that trigger a break in presence. The study of presence would then be concerned with the factors that keep attention focussed within one environment, or promote an attentional shift away from one environment towards the other.

One is either 100% or 0% present, with nothing in between. This does not correspond to a growing amount of empirical data suggesting that presence varies in a continuous fashion depending on media form, media content and user characteristics. One theoretical solution to this problem would be to assume that different levels of presence can be perceived by temporally integrating the number of instants in which presence either does or does not exist (Slater & Steed, 2000). However, it may be interesting to note that the nature of the Gestalt switch between competing environments is different from more traditional Gestalt switches such as the Necker cube or the duck-rabbit Gestalt switch (see picture). When a mediated environment (e.g. a CAVE) competes with the real world (e.g. the computer science laboratory in which the CAVE is embedded), switching to one particular hypothesis interpretation of the incoming sensory stream *does not necessarily overrule* the alternative interpretation completely. Both medium and physical environment are distinct entities which may be perceived *at the same time*, whereas with a traditional Gestalt switch it is *either* the duck *or* the rabbit, but never both. This would indicate that a Gestalt switch may not be the most appropriate metaphor for understanding presence. Rather, a break in presence may be conceived of as an *attentional shift* away from the mediated environment and towards the physical environment, but with the possibility to still feel a sense presence in the mediated environment, albeit to a lesser extent.

6. Neural correlates of presence?

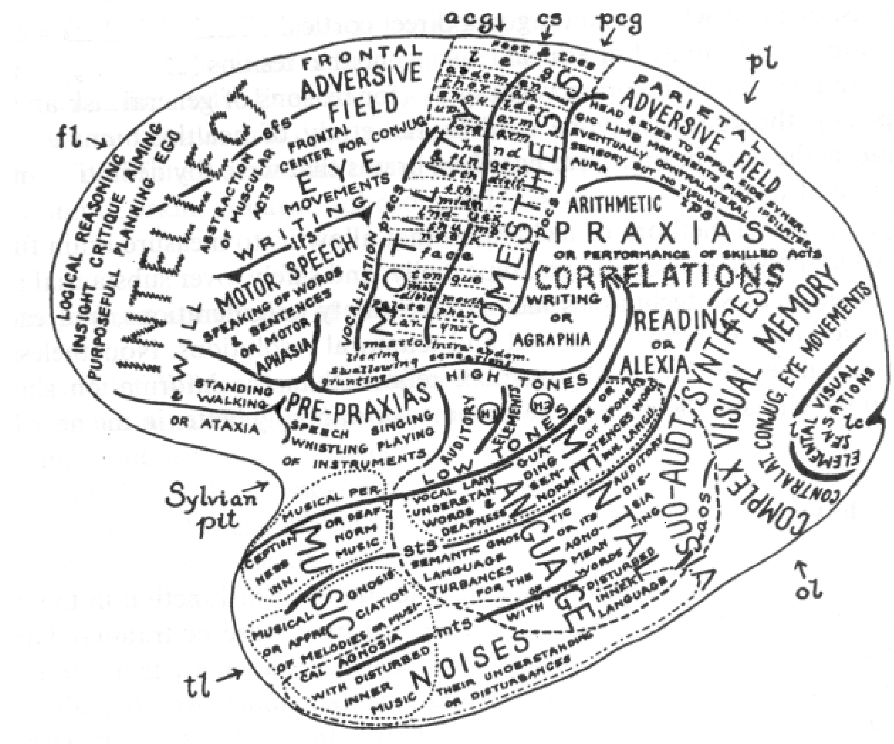
During the 2nd half of the 20th century a collection of relatively non-invasive tools for assessing and localising human brain functions has become available to researchers, leading to an explosion of research in the area of brain mapping, an area previously dominated by lesion studies (e.g. the work of Alexander Luria) and direct cortical stimulation during neurosurgical procedures to alleviate epilepsy symptoms (e.g. Penfield, 1958). Although recording electrical activity through EEG or hemodynamics via PET or functional MRI allows researchers to look inside the healthy brain with varying levels of temporal and spatial resolution, much depends on clever experimental designs in order to be able to make any sense out of the obtained activation patterns.

Based on the previous discussion of presence phenomenology and mental processing, it appears that the experience of presence is a complex, multidimensional perception, formed through an interplay of raw (multi-)sensory data and various cognitive processes – an experience in which attentional factors play a crucial role. Heeter (2001) states it as such: “Presence is a series of moments when cognitive and perceptual reactions are closely tied to current sensory impingements”. However, the exact nature and location of the processing that results in a sense of presence is not known. It appears that the presence experience has a potentially large number of neural processes associated with it. Any attempt to ‘localise’ the presence experience is not unlike attempts at localising consciousness, or intelligence. To paraphrase William James, presence is not a thing, but a process. Exactly what that process is, still remains to be discovered.

At present, attempting to measure neural correlates of presence constitutes what mathematicians would call an *ill-posed* problem – that is, additional constraints are needed to be able to solve it. Presence needs to be unambiguously operationalised, and subdivided into its basic components in order for it to be measurable in a way that will make sense. Relatively simple experiments can be performed to check for elements of perceptual realism and immersion, such as increasing frame rate, enlarging the field of view, providing stereoscopic video, spatial audio, etc. In this way the effects on the brain of changing the bottom-up sensory inputs may be investigated. However, although such manipulations are known to affect the subjective sense of presence, they cannot be regarded as producing presence where first there was none. If we choose to operationalise the essence of presence as a Gestalt switch, we can think of a number of experiments that would introduce breaks in presence or BIPs (Slater & Steed, 2000), comparing an unhindered presence experience with a similar hindered one (i.e. where BIPs have been introduced), while compensating for the brain activity patterns corresponding to the isolated BIP stimuli.

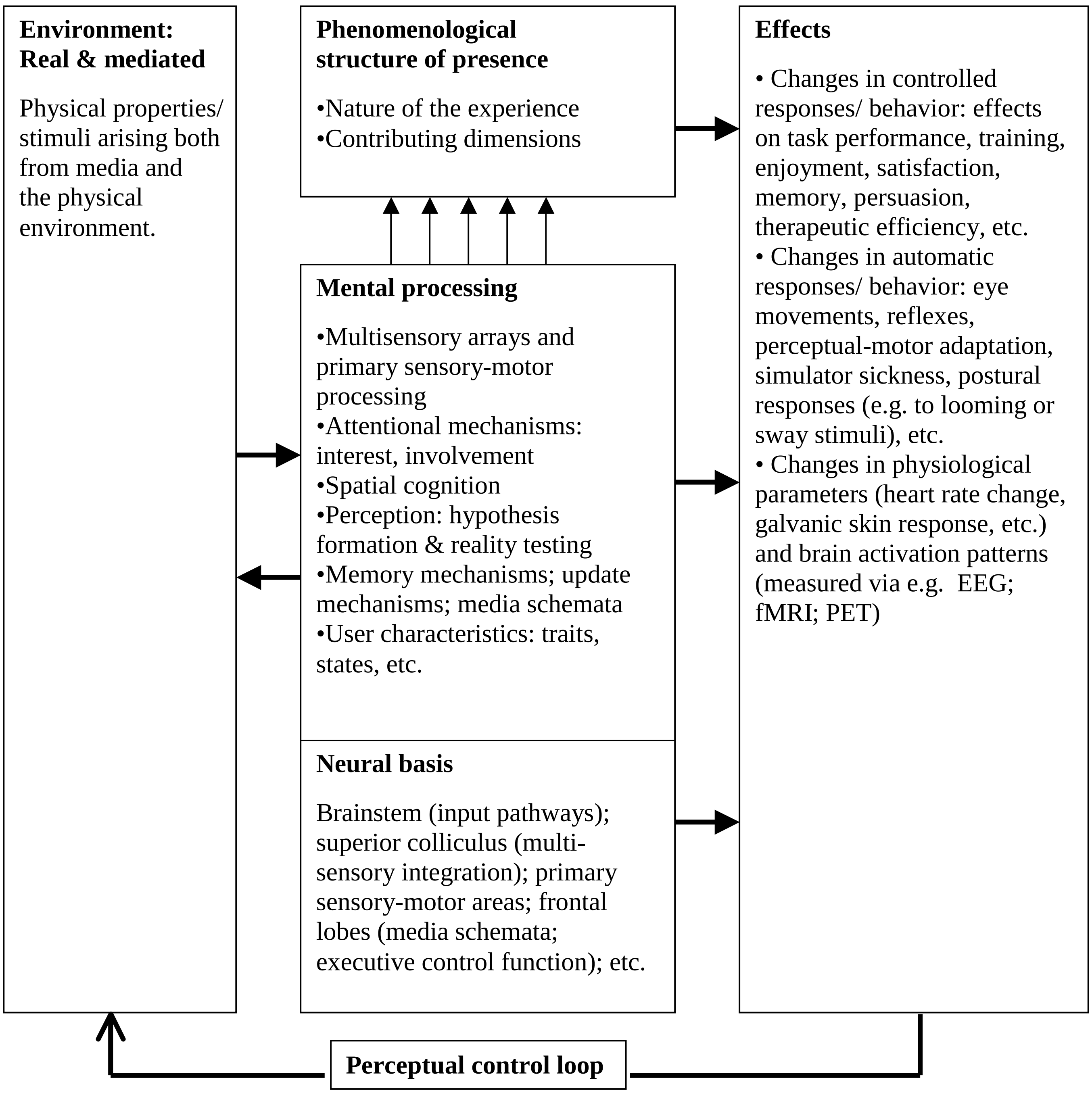
Another, more elegant, but also more complex paradigm, would be to keep the actual perceptual stimulation identical, while changing the *interpretation* of the perceptual hypotheses. An example of such an experiment, although within a better defined problem area, is described in a recent paper by Moore & Engel (2001). They designed an experiment to find out what parts of the brain are involved when we visually perceive the volume of an object, *independent* of image information. They first presented the viewer with an ambiguous shape and measured the fMRI response of the lateral occipital region (LO). Next, a disambiguating gray scale image of the same object was presented, which biased the interpretation of the ambiguous figure as being a three-dimensional volumetric object. Finally, the original ambiguous shape was presented again and the fMRI response remeasured. Now, neural activity in LO increased compared to the first presentation of the ambiguous shape. This experimental paradigm allows to relate the increased activation patterns to the *interpretation* of the stimulus, rather than to the physical stimulus itself, thus providing some insight in the neural basis of top-down perceptual mechanisms.

Aside from the conceptual difficulties and the challenges of designing clever experimental paradigms, there are a number of practical difficulties to overcome as well when attempting to use brain imaging techniques for presence research. For example, being large magnets, MRI scanners are usually not very tolerant to metallic parts in their vicinity. Apart from being a health hazard to careless individuals, this rules out the use of any display devices that contain metallic parts – i.e. HMDs, projectors, CRTs, etc. One could however imagine building an HMD based on non-metallic parts. A more general drawback is the amount of tethering, and body and head fixation that is required for reliable measurements to occur. This will make experiments on interactivity through head or body movements difficult or impossible to perform, but more importantly may by itself be detrimental to the sense of presence. This latter point is particularly salient when using high-speed imaging parameters (e.g. echo planar imaging) routinely used in fMRI, which generates a huge amount of acoustic noise. This will almost certainly pull people back into the reality of being inside an MRI scanner. In addition, it makes auditory experimentation virtually impossible using this imaging technique. One can also foresee problems with wearing an HMD when electrodes need to be placed directly on the scalp. But before attempting to overcome such difficulties we need to have a clear idea what it is exactly that we are trying to measure, and how to design an experiment that does just that.



7. Conclusion

Brains are not evolved to understand virtual reality. When our brain reached its current state of evolutionary development in Africa some 200,000 years ago, what looked like a lion, actually was a lion! And if contemplating the nature of reality at that point would have been a priority, one would have made for an easy lion’s snack. On the other hand, we do seem to have gained some knowledge about media over the years. We don’t run out of movie theatres anymore when a black and white, silent movie is shown of a train arriving at a station. At a cognitive level we have knowledge, one could call them *media schemata*, that tells us what media can do, and what we can expect in terms of sound, pictures, etc. This knowledge will likely inhibit some of our more controllable responses to media (“Don’t be afraid, it’s only a movie”), although still enough of our original response tendencies will shine through in our automatic, unconscious responding. At this level, we respond to mediated stimuli in much the same way as we would to similar, unmediated stimuli.


Environment: Real & mediated
Physical properties/ stimuli arising both from media and the physical environment.
Phenomenological structure of presence
•Nature of the experience
•Contributing dimensions
Mental processing
•Multisensory arrays and primary sensory-motor processing
•Attentional mechanisms: interest, involvement
•Spatial cognition
•Perception: hypothesis formation & reality testing
•Memory mechanisms; update mechanisms; media schemata
•User characteristics: traits, states, etc.
Neural basis
Brainstem (input pathways); superior colliculus (multi-sensory integration); primary sensory-motor areas; frontal lobes (media schemata; executive control function); etc.
Effects
• Changes in controlled responses/ behavior: effects on task performance, training, enjoyment, satisfaction, memory, persuasion, therapeutic efficiency, etc.
• Changes in automatic responses/ behavior: eye movements, reflexes, perceptual-motor adaptation, simulator sickness, postural responses (e.g. to looming or sway stimuli), etc.
• Changes in physiological parameters (heart rate change, galvanic skin response, etc.) and brain activation patterns (measured via e.g. EEG; fMRI; PET)
Perceptual control loop

This fact provides the basis for a number of behavioural and physiological *correspondence measures* of presence. For instance, Freeman, IJsselsteijn and colleagues (Freeman, Avons, Meddis, Pearson, & IJsselsteijn, 2000; IJsselsteijn, de Ridder, Freeman, Avons, & Bouwhuis, 2001) have investigated observers' automatic postural responses to moving video (a sequence of a rally car traversing a curved track at speed) and found that more substantial lateral postural responses occurred when the video was projected stereoscopically than when it was presented monoscopically, corroborating subjective ratings of presence. Another example can be found in the work of Meehan, Insko, Whitton & Brooks (2002) who applied a range of physiological measures to corroborate reported presence, comparing a non-threatening virtual environment to a stressful virtual height situation. They found a significant effect of frame rate (30FPS > 20FPS > 15FPS) and the inclusion of a passive haptic element (a wooden ledge) on presence, both on subjective and physiological measures, with change in heart rate performing best as a correspondence measure, i.e. with the highest reliability, validity and sensitivity.

Generally speaking, the better the mediated stimulation, the less media schemata will signal the mediated nature of the event, and the more our brains will go with what its senses seem to be telling it, taking things at face value. The simulation in our heads is able to run on surprisingly little, building a coherent model of an environment from minimal information, filling in for the missing pieces. This is the basis of presence in relation to current media systems, although clearly more research will need to be devoted to know exactly how much information is optimal for presence in different contexts, and how the different sources of information interact with the individual's mind in establishing a sense of 'being there'. A theoretical basis for presence can provide direction to this research, generating testable hypotheses at various levels of explanation. This will in turn enable refinement of theory and measurement, and stimulate the formulation of alternative viewpoints in the light of new insights and experimental results.

References

Avons, S.E. (1996). Mechanisms of visual perception: A selective review with reference to VR applications, Unpublished document, University of Essex, UK.

Biocca, F., Kim, T. & Levy, M. (1995). The vision of virtual reality. In: Biocca, F. & Levy, M. (eds), *Communication in the age of virtual reality*. Hillsdale, NJ: Lawrence Erlbaum, 3-14.

Clark, A. (1996). *Being There: Putting Brain, Body and World Together Again*. MIT Press

Cutting, J.E., & Vishton, P.M. (1995). Perceiving layout and knowing distances: The integration, relative potency, and contextual use of different information about depth. In: Epstein, W. and Rogers, S. (eds.), *Perception of Space and Motion*. San Diego: Academic Press, pp. 69-117.

Dennett, D. (1991). *Consciousness Explained*. Boston: Little, Brown, and Co.

Ellis, S.R. (1996). Presence of mind: A reaction to Thomas Sheridan's 'Further musings on the psychophysics of presence'. *Presence: Teleoperators and Virtual Environments 5*, 247-259.

Flach, J.M., & Holden, J.G. (1998). The reality of experience: Gibson's way. *Presence: Teleoperators and Virtual Environments 7*, 90-95.

Freeman, J., Avons, S. E., Meddis, R., Pearson, D. E. & IJsselsteijn, W.A. (2000). Using behavioural realism to estimate presence: A study of the utility of postural responses to motion-stimuli. *Presence: Teleoperators and Virtual Environments 9*, 149-164.

Gibson, J.J. (1966). *The Senses Considered as Perceptual Systems*. Boston: Houghton Mifflin.

Gibson, J.J. (1979). *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin.

Gregory, R L. (1998) *Eye and brain: The psychology of seeing* (5th Edition). Oxford University Press.

Grusser, O.-J. (1983). Multimodal structure of the extrapersonal space. In: Hein, A. & Jeannerod, M. (eds.), *Spatially Oriented Behavior*. New York: Springer-Verlag, 327-352.

Heeter, C. (1992). Being There: The Subjective Experience of Presence. *Presence: Teleoperators and Virtual Environments 1*, 262-271.

Heeter, C. (2001). Reflections on real presence by a virtual person. Paper presented at Presence 2001 - The 4th Annual International Workshop on Presence, Philadelphia, USA. May 21-23, 2001.

Hoffman, D.D. (1998). *Visual Intelligence: How We Create What We See*. New York: W.W. Norton and Co.

IJsselsteijn, W.A., de Ridder, H., Freeman, J., & Avons, S.E. (2000). Presence: Concept, determinants and measurement. *Proceedings of the SPIE 3959,* 520-529. [Online: http://www.presence-research.org/papers/SPIE_HVEI_2000.pdf]

IJsselsteijn, W.A., de Ridder, H., Freeman, J., Avons, S., & Bouwhuis, D. (2001). Effects of stereoscopic presentation, image motion and screen size on subjective and objective corroborative measures of presence. *Presence: Teleoperators and Virtual Environments 10,* 298-311. [Online: http://www.presence-research.org/papers/presence2001.pdf]

IJsselsteijn, W.A., de Ridder, H., Hamberg, R., Bouwhuis, D. & Freeman, J. (1998). Perceived depth and the feeling of presence in 3DTV. *Displays 18*, 207-214. [Online: http://www.presence-research.org/papers/displays1998.pdf]

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2000). Development of a new cross-media presence questionnaire: The ITC-sense of presence inventory. In: IJsselsteijn, W.A., Freeman, J. & de Ridder, H. (eds.), *Proceedings of PRESENCE 2000 - 3rd International Workshop on Presence* (CDROM), Delft, The Netherlands, 27-28 March 2000. [Online:http://homepages.gold.ac.uk/immediate/immersivetv/P2000-lessiter.htm]

Levin, D.T., & Simons, D.J. (2000). Perceiving stability in a changing world: Combining shots and integrating views in motion pictures and the real world. *Media Psychology 2*, 357-380.

Lombard, M., & Ditton, T.B. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication 3(2)*. [Online: http://www.ascusc.org/jcmc/vol3/issue2/lombard.html]

Meehan, M., Insko, B., Whitton, M. & Brooks, F.P. (2002). Physiological measures of presence in virtual environments. Presented at SIGGRAPH 2002, San Antonio, USA, 23-25 July 2002.

Moore, C. & Engel, S.E. (2001). Neural response to perception of volume in the lateral occipital complex. *Neuron 29*, 277-286.

Penfield, W. (1958). *The Excitable Cortex in Conscious Man*. Liverpool University Press.

Previc, F.H. (1998). The neuropsychology of 3-D space. *Psychological Bulletin 124*, 123-164.

Reeves, B., Thorson, E., Rothschild, M., McDonald, D., Hirsch, J. & Goldstein, R. (1985). Attention to television: Intrastimulus effects of movement and scene changes on alpha variation over time. *International Journal of Neuroscience 27*, 241-255.

Rizzolatti, G. & Camarda, R. (1987). Neural circuits for spatial attention and unilateral neglect. In: Jeannerod, M. (ed.), *Neurophysiological and neuropsychological aspects of spatial neglect*. pp. 289-313. Amsterdam: Elsevier Science.

Rizzolatti, G., Fadiga, L., Fogassi, L., & Gallese, V. (1997). The space around us. *Science, 277,* 190-191.

Sadowski, W., & Stanney K. (2002). Presence in Virtual Environments. In Stanney, K. M. (ed.), *Handbook of Virtual Environments: Design, Implementation, and Applications*. Mahwah, NJ: Lawrence Elbaum Associates, Publishers.

Schubert, T., Friedman, F., & Regenbrecht, H. (1999). Decomposing the sense of presence: Factor analytic insights. Paper presented at the 2nd International Workshop on Presence, University of Essex, UK, 6-7 April 1999. [Online: http://www.uni-jena.de/~sth/vr/insights.html]

Sedgwick, H.A. (2001). Visual space perception. In: Goldstein, E.B., (ed.), *Blackwell Handbook of Perception*. Oxford: Blackwell Publishers Ltd.

Sheridan, T. B. (1992). Musings on telepresence and virtual presence. *Presence: Teleoperators and Virtual Environments 1*, 120-126.

Slater, M. (2001). The Sixth Sense. *Presence-Connect.* [Online: http://www.presence-connect.com/]

Slater, M., & Steed, A. (2000). A virtual presence counter. *Presence: Teleoperators and Virtual Environments 9*, 413-434.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and Virtual Environments 6*, 603-616.

Stark, L. (1995). How virtual reality works! The illusions of vision in “real” and virtual environments. *Proceedings of SPIE 2411*, 277-287.

Solomon, R.J. (2002). As if you were there: Matching machine vision to human vision. *The Hybrid Vigor Journal V1.3:4*. [Online: http://www.hybridvigor.net/human/pubs/HVvision.pdf]

Subramanian, S. & IJsselsteijn, W.A. (2000). A survey of spatial 3D object manipulation techniques. In: Paris, C., Ozkan, N, Howard, S. & Lu, S. (eds.). *Proceedings of OZCHI 2000, Interfacing Reality in the New Millenium*, 330-337.

Zahorik, P., & Jenison, R.L. (1998). Presence as being-in-the-world. *Presence: Teleoperators and Virtual Environments 7*, 78-89.