Spatial Presence

EXPLICATION FROM AN ARCHITECTURAL POINT OF VIEW FOR ENHANCING DESIGN VISUALIZATION TOOLS

Bimal Balakrishnan College of Communications, Penn State University, U.S.A.
Katsuhiko Muramoto Department of Architecture, Penn State University, U.S.A.
Loukas N. Kalisperis Department of Architecture, Penn State University, U.S.A.
and Cyprus Institute, Nicosia, Cyprus

This paper provides the theoretical foundation for understanding the concept of spatial presence. This is important for improving architectural visualization tools so as to capture the experiential aspects of space. The paper is organized into three sections. The first section explicates the concept of spatial presence by identifying various conceptualizations of spatial presence in the literature and performing a meaning analysis. It then proceeds to examine mechanisms underlying the formation of spatial presence. The paper concludes by offering initial guidelines for improving the nature of digital tools to enhance the feeling of spatial presence.

INTRODUCTION

The concept of presence, often defined as the subjective experience of 'being there' in a mediated environment, has generated a great deal of interest in diverse disciplines. Architects have long sought various representational media to "occupy" the spaces conceived in their mind's eye. Computer based visualizations are commonplace and are becoming increasingly realistic, immersive and navigable. The increased frequency with which proposed architectural solutions are designed and evaluated solely using computers, gives great significance to the concept of presence or more precisely that of spatial presence. Despite a large volume of literature related to presence, mechanisms underlying the formation of presence experience are still poorly understood. Kwan Min Lee (2004b) attributes this to the fact that most presence-related research deal with the "what" question focusing on the causes and effects of presence as opposed to the "why" question focusing on the enabling mechanism. New tools afford new ways of exploring virtual spaces.

The main goal of this paper is to improve our understanding of how presence, or more specifically spatial presence, is formed. This understanding can then become the foundation for development of 3-D visualization tools and techniques that focus on capturing the architectural experience. This paper is expected to contribute to our theoretical understanding of spatial presence formation as well as provide practical implications for a wide variety of navigable spatial environments from architectural visualizations to games and immersive virtual reality simulations. This paper begins with an explication of the concept of presence and spatial presence. This is followed by a review of the literature on various mechanisms of spatial presence formation from diverse theoretical traditions.

SPATIAL PRESENCE, EXPLICATED

Presence has generated interest in highly diverse disciplines and this has led to a variety of definitions and theoretical ambiguity. Earlier approaches generated from a technological perspective have failed to distinguish it from related concepts in psychology and media theory. Since then, there have been numerous attempts to explicate it including an earlier attempt by Lombard and Ditton (1997) and a more recent one by Lee (2004a). The challenges in explicating presence arise in part because different disciplines have different foci for research. Given the context of architecture, the scope of this explication is limited to perhaps what may be treated as a sub-concept of presence, which can be referred to as spatial presence.

PRIMITIVE TERMS

Before elaborating on a concept such as presence, the existence of person, space and time must be accepted from which inferences can be made. Person and time are treated as primitive terms in communication (Chaffee 1991). While space can be conceptualized in different ways (e.g. poetic space, metaphorical space, etc.), for the purpose of this explication, we will treat space as a primitive term with its commonly understood meaning within the context of architecture.

PRELIMINARY DEFINITION

The Webster's dictionary defines presence as "the fact or condition of being present" and its adjective present is defined as "being at a specified or understood place." Integration of the above two is implied in Kim and Biocca's (1997) definition of presence as the "fact or condition of being present at the specified or understood place." Being a psychological concept, presence is affected by individual differences as well as a number of psychological and environmental factors. The sense of presence can also vary with time as a function of the stimulus. Thus, presence as a variable is expected to show both cross-sectional as well as process variance.

THEORETICAL DEFINITIONS

Presence research has implications for diverse disciplines, but in our opinion most importantly for architecture. A recent explication by Lee (2004a, 37) with the goal of a formulating a unified definition of the term presence, defines it as "a psychological state in which virtual (para-authentic or artificial) objects are experienced as actual objects in either sensory or non-sensory ways." Here the term object is used in the broad sense to denote physical objects, social actors, or virtual representations of the self. He identifies three corresponding typologies of presence: physical, social and self.

While Lee (2004a) elaborates that the definition includes "environments," he explicitly rejects the requirement of "self-existence" or "being-inside" a virtual world and thus the need for transportation as a pre-requisite for physical presence to occur. While this would perhaps help to advance a unified definition of presence, it falls short on a few counts, both theoretically and operationally and thus cannot be used directly in architectural research. The theoretical issues are listed here. First, it lacks specificity since it does not discern the differences between physical, psychological and virtual realities. Second and perhaps more importantly, it deviates from the common conceptualization of "being-there." There is a long tradition of defining presence, as 'being-there' and it would thus be worthwhile to revisit those definitions

in order to reconceptualize spatial presence.

Minsky (1980), who first coined the word telepresence, used it to refer to teleporting your actions in a given location to a remote but real location using instrumental devices that feel and work without any significant noticeable difference. While he stresses the importance of sensory feedback, he does not require the feeling of non-mediation to achieve telepresence. For Minksy (1980), the biggest challenge to developing telepresence is achieving a sense of "being-there." Hendrix and Barfield (1996) use the term to refer to the feeling of being present in a remote but real environment and distinguishes it from virtual presence which is the feeling of being present in a computer-generated environment. Draper, Kaber, and Usher (1998) combines the two and uses the term to describe feeling present in either a remote or a computer-generated virtual environment.

The term presence, for Steuer (1992), deals with the experience of a person's immediate physical environment, i.e. the natural environment. Steuer (1992) defines telepresence as "the experience of presence in an environment by means of a communication medium." This definition of telepresence as subjective experience of being-in a place other than the immediate physical space is reflected by others such as Witmer and Singer (1998) as well as Waterworth and Waterworth (2003). Steuer operationalizes telepresence as the degree to which one feels present in the mediated environment as opposed to the subject's immediate physical environment. Here non-mediation is the important aspect.

This approach is further elaborated by Sas and O'Hare (2003) to include imaginary worlds and define presence as "a psychological phenomenon through which one's cognitive processes are oriented toward another world, either technologically mediated or imaginary, to such an extent that he or she experiences mentally the state of being (there), similar to one in the physical reality, together with an imperceptible shifting of focus of consciousness to the proximal stimulus located in that other world."

For Biocca, Harms and Burgoon (2003) telepresence, spatial presence and physical presence, all refer to the same sense of "being there" in a virtual place. Biocca et al. (2003) take Steuer's definition one-step further. Telepresence, according to them, is "the phenomenal sense of 'being there' including automatic responses to spatial cues and the mental models of mediated spaces that create the illusion of place"(Biocca, et al. 2003, 459). The notion of environmental presence (Heeter 1992) expands this idea again by defining it as the extent to which the environment is aware of and responds to the user action by modifying in some aspects of it. For Zahorik and Jenison (1998), presence is tantamount to successfully supported action in the environment.

Implicit in the "being there" approach to defining presence is Gerrig's (1993) notion of transportation into a narrative environment created by the medium. In most conceptualizations of spatial presence, the direction of transportation is from the physical space of the user to the mediated space. Lombard and Ditton's (1997) definition also includes "it is here" whereby another place and/or its contents are transported to the user in addition to the common idea of "being there."

Vorderer et al. (2003) define spatial presence as a "binary experience, during which perceived self location and, in most cases, perceived action possibilities are connected to a mediated spatial environment, and mental capacities are bound by the mediated environment instead of reality." Spatial presence is seen here as resulting from a two step process, the first of forming a spatial situation model in the mind based on the media cues and then of testing whether the primary egocentric reference frame (PERF) is located in the mediated space (Vorderer et al. 2003).

MEANING ANALYSIS

Theoretical definitions of presence can be grouped on the nature of reality with which the subject is interacting: physical, psychological, or virtual. Another way to organize the definitions would be based on which dimension of spatial presence is emphasized—'being there,' 'responsiveness' or 'supporting action.' The definition Vorderer et al. (2003) give of spatial presence seems to be appropriate but their treatment of spatial presence as a binary on/off variable fails to acknowledge that the sense of spatial presence varies as a function of time, depending on temporal context of the stimuli. Since the study is about navigation in a virtual environment, a comprehensive definition can be arrived at, building on Wirth et al. (2007), which includes the dimensions of "being there," "responsiveness" (e.g. collision detection) and "supporting action" (e.g. navigability).

FACTORS AFFECTING PRESENCE

Presence is a multi-dimensional concept and is dependent on a large number of inter-related factors (Kalawsky, Bee, and Nee 1999). The number of factors that affect presence are so numerous that as Lee (2004) points out, there have been many attempts at a classification system from a simple exogenous (technology-centric) /endogenous (user-centric) one (Slater and Usoh 1993) to more sophisticated ones. Kalawsky, Bee and Nee (1999) classify the parameters determining presence into categories of demand and supply of attentional resources, understanding of situation, information and technologi-

cal factors. IJsselsteijn, de Ridder, Freeman and Avons (2000) group the variables affecting presence broadly into four groups: the extent and fidelity of sensory information such as screen size, resolution and field of view, the match between sensors and display, media content and user characteristics. A more exhaustive listing of factors affecting presence is given in Lee (2004b) and Nash, Edwards, Thompson and Barfield (2000).Compared to sensory modalities or variables, studies that deal with interactivity—especially concerning navigability and their contribution to presence, are relatively low in number. While interactivity and more specifically navigation can be seen as potential contributors to the experience of spatial presence, the exact process is still not quite understood.

MECHANISMS OF SPATIAL PRESENCE FORMATION

Despite the large volume of literature on presence, it is still a poorly understood phenomenon particularly the mechanism of presence formation. This is due to the fact that most of the presence studies including empirical ones have focused on the causes and effects of presence rather than exploring why presence occurs (Lee 2004b). A serious drawback of most of these presence-formation explanations is that there is little achieved by way of testing these mechanisms empirically. Another challenge in presence related studies lies in the lack of clarity regarding the philosophical foundations underlying these different explanations. The following sub-sections summarize previous attempts at understanding formation of spatial presence from diverse theoretical perspectives.

EVOLUTIONARY PSYCHOLOGY & THE MEDIA EQUATION (TME) PERSPECTIVE

Lee (2004b) attempts to explain presence from 'the media equation perspective.' Coming from an evolutionary psychology perspective, this approach assumes the modularity of the human mind. In other words, this approach treats the brain as having innately developed and domain-specific causal reasoning modules for explaining or understanding situations in both the physical and social worlds, which are critical for survival. Lee (2004b) attributes spatial-presence formation to the mindless application of a folk-physics module to virtual objects on screen. The term 'folk-physics' here refers to knowledge of causal relationships in the physical world developed innately since childhood without explicitly analyzing the mechanisms underlying the cause and effect. This approach is in direct contrast to the early approaches to presence as an experience arising from "willing suspension of disbelief" and assumes an automatic as opposed to controlled processing of the virtual stimuli. This knowledge of causal reasoning module is particularly triggered by the media cues such as image size and motion, which are linked to ones' survival instinct.

While the media equation perspective stands out as an oddity, most of the presence definitions and explanations approach it from either an immersion point of view (Heeter 1992; Witmer and Singer 1998) or an activity based view (Flach and Holden, 1998; Zahorik and Jenison 1998). Biocca (2001) has especially argued for integrating these diverse viewpoints within a more general approach to understanding the nature of mind and agency.

SPATIAL PRESENCE FORMATION FROM A SITUATED COGNITION PERSPECTIVE

Antonella Carassa and her colleagues (Carassa, Morganti, and Tirassa 2004; Carassa, Morganti, and Tirassa 2005) attempt to explain presence formation from the broader perspective of situated cognition. The situated cognition approach attempts to understand spatial cognition from a subjective perspective and from an interaction point of view rather than building on behaviors (Tirassa, Carassa, and Geminiani, 2000). This is different from the computational approach to cognition proposed by cognitive science. According to Carassa, Morganti and Tirassa (2005, 387), "presence depends on the proper integration of aspects relevant to an agent's movement and perception, her actions, and to her conception of the overall situation in which she finds itself, as well as on how these aspects mesh with the possibilities for action afforded in the interaction with the virtual environment." They conceive an agent's interaction with the virtual world as having three levels, that of situation, action and movement—each nested in and informing the other. The idea here is that movement or at a higher level, action does not exist in isolation from the larger situation the subject finds himself/herself in. Carassa and her colleagues differ from others in that, their approach treats a subject in a mediated environment as an agent who carries his/her own narrative while interacting in the world (real or artificial) as opposed to a nomad who is purposeless in an objectively given world. Here the importance is not on the match between the external world and the internal representation, which does not capture the nature of human agency. The emphasis here is on the quality of the interaction afforded by the medium rather than the representational isomorphism with a corresponding real world situation. Affordance here is treated as representation, which meshes different aspects including cultural aspects. Presence here is approached from a subjective perspective, which is rooted in the meaningful situation in a continuum

between the past and the future that the agent finds himself/herself in.

DISTAL ATTRIBUTION AND PRESENCE

Presence has been suggested as best conceptualized as a subset of the mind-body problem (Biocca 1997 2001). The phenomenon of presence is closely connected to the phenomenon of distal-attribution or externalization. We attribute the perception of objects around us not to the impacts they have on our sensory organs, but to the objects themselves in the external space beyond the limits of the sense organs. The similarity of this 'externalization' or 'distal attribution' phenomenon to that of presence was first made by Loomis (1992). Assuming the subjective division of the phenomenal world into 'self' and 'non-self,' distal attribution occurs when the commands of the central nervous system (CNS) to the body (efference) corresponds to the input from the sensory organs (afference) (White 1970). Loomis (1992) expands on this idea to include the need to internally represent the linkage between afference and efference. As long as the subject can successfully represent the linkage internally (due to the extensions being simple or learn to represent the linkage through training), the linkage will appear transparent, leading to distal attribution. A similar idea from an information processing point of view is expressed by Sheridan (1999) who suggests that true reality can never be known, but only estimated due to the noise affecting the afferent and efferent filters.

TWO-STEP MODEL OF SPATIAL PRESENCE FORMATION FROM SPATIAL SITUATION MODEL (SSM) THROUGH CONFIRMATION OF 'MEDIUM-AS-PERF HYPOTHESIS'

Vorderer et al. (2003) have postulated a two-step model of spatial presence formation. The first step involves the formation of a mental model of the space (Spatial Situation Model) that is communicated through the media (irrespective of the level of abstraction of media, e.g. text). Spatial presence emerges when a particular perceptual hypothesis referred to by the authors as 'medium as Primary ego-centric reference frame' (a.k.a. medium as PERF hypothesis) is confirmed. Both media as well as user characteristics play a critical role at each stage of this model. In forming the spatial situation model (SSM), user characteristics such as voluntary and involuntary attention and media characteristics relating to both form and content, particularly spatial cues, are important. Individuals, in order to orient themselves within a space and navigate through it, maintain an egocentric reference frame, i.e. mental model of the world organized from a first person perspective. When presented with a mediated space, it provides the subject with another egocentric reference frame in addition to the one offered by the individual's immediate physical world. Vorderer et al. (2003) argue that spatial presence emerges when the 'medium-as-PERF' hypothesis is confirmed repeatedly. Persistence of the mediated environment, afferent feedback from the mediated world which matches the user's expectations and interactivity all help confirm and sustain the 'medium-as-PERF' hypothesis leading to spatial presence formation.

IMPLICATIONS SPATIAL PRESENCE FOR ARCHITECTURAL DESIGN

SPATIAL PRESENCE AND DESIGN VISUALIZATION

Beginning students of architecture have difficulty visualizing space, not just in terms of its extent and organization but also regarding its experiential aspects. Sophisticated modeling tools and the ability to render photorealistic images afforded by current computer-aided design software have expanded our abilities to visualize and simulate spaces. However, capturing or simulating the experiential aspects of space is still an enormous challenge. Space is never experienced from a single static viewpoint, but results from one's movement through it. Current tools for architectural visualization are rarely full scale (except perhaps in full scale immersive VR environments) and always place the designer outside of the representation and necessitate a mental leap on the part of the designer. Spatial-presence, which involves self-location and exploration of action possibilities in the mediated space, can therefore be used as a theoretical foundation for the development of visualization tools to overcome the above shortcoming. Architectural visualization tools that can enable a sense of presence may provide designers an opportunity to 'inhabit' the spaces under design and evaluate their experiential aspects. The next sections discuss some of the limitations of current CAD tools and how we can build on spatial-presence theory to overcome some of those limitations.

LIMITATIONS OF CURRENT VISUALIZATION TOOLS

Almost all of the current CAD packages are aimed at later stages of the design process and their primary goal is to accurately communicate the spatial characteristics to consultants and further to facilitate construction on site. Most 3-D modeling packages have their roots in mechanical engineering and thus focus on solid modeling as opposed to void modeling. While many of these software packages have animation capabilities, they are based on paradigms borrowed from animation and cinema. The characteristics of commonly available digital tools for design visualization seem to emphasize the artifact rather than the spatial experience. This is evident by

the fact that the interactions of the designer with the representations are driven more by the efficiency of human-computer interactions than by the experiential aspects of the interaction. Current rendering technologies have made great strides in achieving representational isomorphism through increased photorealism. Experiential congruence with a corresponding real world space is still a challenge. While the current tools and their functionality are critical for externalizing design ideas in the form of representations, more work needs to done with respect to exploring them to improve the experiential aspects of these simulations. We conclude this paper by providing some initial guidelines for architectural visualization tools to enhance spatial presence and thereby increase experiential quality.

GUIDELINES FOR IMPROVING SPATIAL-PRESENCE IN ARCHITECTURAL VISUALIZATION TOOLS

Digital tools available at our disposal today have achieved a high level of sophistication for representation. What is immediately needed is the ability to explore the experiential aspects. This is perhaps not difficult to achieve, given the level of experiential quality of some of the 3-D games today when played even on a computer screen. Design tools should have the ability to easily switch from a representational mode to an experiential mode without complicated programming or scripting requirements. Design can be considered to be an iterative 'propose-critique-modify' process and the ease of switching from a representational mode to an experiential mode is critical to avoid delays. The game mode (though it still needs to be pre-programmed) in Blender (an open source software) is a step in the right direction. The need to program interactions available in the game engine mode are time consuming and tend to slow down and thus reduce the number or propose-critique-modify cycles of design.

In accordance with the activity based theories of presence such as those proposed by Zahorik and Jenison (1998), the interfaces of architectural visualization tools should afford more interactivity which can also increase a sense of agency. While most digital representational environments for architecture are good at enhancing spatial situation models through a variety of monocular dept cues, further cues are needed for enhancing immersion and involvement. While visual cues are perhaps most critical for the architectural experience, these cues should go beyond photo-realism and should include *folk-physics* as proposed by Lee (2004b). The presentation modes of these tools should afford interactivity in such a manner that the interface is rendered transparent. Interaction paradigms of these environments should relate to expectations with respect to the behavior of spaces (e.g. gravity, collision detection) and include afferent (at least visual, e.g. motion blur) feedback, which can enhance the formation of spatial situation models and make positive contributions to confirming the "medium-as-PERF" hypothesis leading to spatial presence.

The digital tools should not only focus on representational affordances but also on navigability, i.e. the affordance for navigation. The most critical affordance will concern locomotion through the 3-D spatial representation. Traversability is the affordance to move larger distances in a simulated architectural environment resulting from constraints imposed by the environment as well as the extent of user control for steering. Environmental constraints arise from the combination of constraints imposed by the environment on direction and orientation (i.e. degrees of freedom), speed and velocity of motion, as well as physicality, analogous to the real world such as gravity and collision detection. Steering control is determined by the level of user control in specifying the frame of reference as well as the position, velocity and acceleration at each step/segment of the movement. While implementing the travel tools, which in effect determine traversibility, selection of direction of motion, velocity and acceleration, and input conditions should all contribute to increasing user attention and involvement. Earlier in the paper we discussed the importance of being able to mentally represent the linkage between efference and afference for the discount the mediated nature of the spatial encounter and experience spatial presence. Thus, the interface and interaction techniques should be a natural extension of the users' actions or grounded in common metaphors (such as walking, flying etc.) that are easily accessible to the user.

This paper explicated the concept of spatial presence, examined the underlying mechanisms leading to its formation and offered suggestions regarding the nature of digital tools to enhance a feeling of presence. Our current work investigates the impact of navigability affordances on spatial presence and is in advanced stages of experimental design for empirical evaluations. Once the data is analyzed and if support is found for mechanisms of spatial presence formation discussed above, the next step will be to develop a component for current digital tools that can help visualize the experiential aspects of architectural space.

REFERENCES

Biocca, Frank. 2001. Inserting the Presence of Mind into a Philosophy of Presence: A Response to Sheridan and Mantovani and Riva. *Presence: Teleoperators & Virtual Environments* 10(5):546-56.

———. 1997. The Cyborg's Dilemma: Progressive Embodiment in Virtual Environments. Review of Reviewed Item. *Journal of Computer-Mediated Communication*, 2. htttp://ascusc.org/jcmc/vol3/issue2/biocca2.html.

Biocca, Frank, Chad Harms, and Judee K. Burgoon. 2003. Toward a More Robust Theory and Measure of Social Presence: Review and Suggested Criteria. *Presence: Teleoperators & Virtual Environments* 12(5):456-80.

Carassa, A., F. Morganti, and M. Tirassa. Movement, Action, and Situation: Presence in Virtual Environments. *Paper presented at the 7th Annual International Workshop on Presence (Presence 2004)*, Valencia, Spain, 13-15 October 2004. http://www.temple.edu/ispr/prev_conferences/proceedings/2004/Carassa,%20Morganti,%20Tirassa.pdf

Carassa, Antonella, Francesca Morganti, and Maurizio Tirassa. 2005. A Situated Cognition Perspective on Presence. In Bara, Bruno G. and Barsalou, lawrence and Bucciarelli, Monica, Eds. Proceedings of *the 27th Annual Conference of the Cognitive Science Society, pp.384-389, Stresa, Italy*.

Chaffee, Steven H. 1991. *Explication*. Newbury Park, CA: Sage.

Draper, John V., David B. Kaber, and John M. Usher. 1998. Telepresence. *Human factors* 40, (3):354-75.

Flach, J. M., and J. G. Holden. 1998. The Reality of Experience: Gibson's Way. *Presence: Teleoperators & Virtual Environments* 7(1):90-95.

Gerrig, R. J. 1993. *Experiencing Narrative Worlds: On the Psychological Activities of Reading*. New Haven: Yale University Press.

Heeter, Carrie. 1992. Being There: The Subjective Experience of Presence. *Presence: Teleoperators & Virtual Environments* 1(2):262-71.

Hendrix, C., and W. Barfield. 1996. Presence within Virtual Environments as a Function of Visual Display Parameters. *Presence: Teleoperators and Virtual Environments* 5: 274-89.

Ijsselsteijn, W. A., H. de Ridder, J. Freeman, and S. E. Avons. 2000. Presence: Concept, Determinants and Measurement. In Proceedings of *SPIE - Human Vision and Electronic Imaging Conference, San Jose, CA,520-529.*

Kalawsky, R., S. T. Bee, and S. P. Nee. 1999. Human Factors Evaluation to Aid Understanding of Virtual Interfaces. *BT Technology* 17(1):128-41.

Kim, T., and F. Biocca. 1997. Telepresence Via Television: Two Dimensions of Telepresence May Have Different Connections to Memory and Persuasion. Review of Reviewed Item. *Journal of Computer-Mediated Communication*, 2. http://jcmc.indiana.edu/vol3/issue2/kim.html.

Lee, Kwan Min. 2004a. Presence, Explicated. *Communication Theory* 14(1):27-50.

———. 2004b. Why Presence Occurs: Evolutionary Psychology, Media Equation, and Presence. *Presence: Teleoperators & Virtual Environments* 13(4): 494-505.

Lombard, M., and T. Ditton. 1997. At the Heart of It All: The Concept of Presence. *Journal of Computer-Communication*, 2. http://jcmc.indiana.edu/vol3/issue2 /lombard.html.

Loomis, Jack M. 1992. Distal Attribution and Presence. *Presence: Teleoperators & Virtual Environments* 1(1):113-19.

Minsky, M. 1980. Telepresence. *Omni*, June, 45-51.

Nash, Eric B., Gregory W. Edwards, Jennifer A. Thompson, and Woodrow Barfield. 2000. A Review of Presence and Performance in Virtual Environments. *International Journal of Human-Computer Interaction* 12(1):1-41.

Sas, Corina, and Gregory M. P. O'Hare. "Presence Equation: An Investigation into Cognitive Factors Underlying Presence." *Presence: Teleoperators & Virtual Environments* 12, no. 5 (2003): 523-37.

Sheridan, Thomas B. 1999. Descartes, Heidegger, Gibson, and God: Toward an Eclectic Ontology of Presence. *Presence: Teleoperators & Virtual Environments* 8(5):551-59.

Slater, M., and M. Usoh. 1993. Representation Systems, Perceptual Position, and Presence in Immersive Virtual Environments. *Presence: Teleoperators & Virtual Environments* 2(3): 221-33.

Steuer, Jonathan. 1992. Defining Virtual Reality: Dimensions Determining Telepresence. *Journal of Communication* 42(4):73-93.

Tirassa, Maurizio, Antonella Carassa, and Giuliano Geminiani. 2000. A Theoretical Framework for the Study of Spatial Cognition. In *Spatial Cognition: Foundations and Applications*, ed. S. O'Nuallain pp.19-31. Amsterdam: Benjamins.

Vorderer, P., W. Wirth, T. Saari, F. R. Gouveia, F. Biocca, F. Jäncke, S. Böcking, T. Hartmann, C. Klimmt, and H. Schramm. 2003. Constructing Presence: Towards a Two-Level Model of the Formation of Spatial Presence. *Unpublished report to the European Community, Society & Technology (IST) Program, Project Presence: MEC (IST-2001-37661). Hannover, München, Helsinki, Porto, Zurich.*

Waterworth, J. A., and E. L. Waterworth. 2003. The Core of Presence: Presence as Perceptual Illusion. *Presence-Connect* 3(3). http://www.presence-connect.com/

White, Benjamin W. 1970. Perceptual Findings with the Vision-Substitution System. *IEEE Transactions on Man-Machine Systems* 11(1):54-58.

Wirth, Werner, Tilo Hartmann, Saskia Böcking, Peter Vorderer, Christoph Klimmt, Holger Schramm, Timo Saari, Jari Laarni, Niklas Ravaja, Feliz Ribeiro Gouveia, Frank Biocca, Ana Sacau, Lutz Jäncke, Thomas Baumgartner, and Petra Jäncke. 2007. A Process Model of the Formation of Spatial Presence Experiences. *Media Psychology* 9(3):493-525.

Witmer, Bob G., and Michael J. Singer. 1998. Measuring Presence in Virtual Environments: A Presence Questionnaire. *Presence: Teleoperators & Virtual Environments* 7(3):225-40.

Zahorik, Pavel, and Rick L. Jenison. 1998. Presence as Being-in-the-World. *Presence: Teleoperators & Virtual Environments* 7(1):78-89.