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Can we resolve the book, the physical reality, and the dream state problems? From the two-pole to a three-pole model of shifts in presence

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Abstract

Presence research may have inherited what is labeled the two pole model of presence from its origins in telerobotics and telepresence research. A logical engineering model that saw presence as only moving between physical and virtual space became a psychological model of presence shifts. Psychological theories based on the two pole model have been troubled by an inability to resolve theoretical and observational inconsistencies such as those labeled the book problem, the physical reality problem, and the dream state problem. It is suggested that these problems are just three faces of one problem: the failure of the two pole model to adequately incorporate the roles of mental imagery and spatial attention in driving presence.

An outline of the Three Pole Model of Presence is introduced. Once a third pole, mental imagery space, is added, it appears that the book, physical reality, and dream state problems may be just different situations involving shifts of presence to mental imagery space and a withdrawal of attention from sensorimotor stimuli. Compared to the standard two pole models, the Three Pole Model appears better able to resolve the logical and observational challenges summarized in the book, physical reality, and dream state problems.

Keywords*: human-computer interaction, presence, spatial cognition*

1. The standard two pole model of presence

Research on presence has been dominated by what can be called the standard or two pole psychological model of presence. See Figure 1. The fundamental assumption of the two pole model is that media users are present in either virtual or the physical space. What is most often called spatial presence or physical presence oscillates between two poles: the virtual space and the physical space. A related assumption is that increases in sensorimotor immersion are the principal variables influencing movement from physical space to virtual space. The two pole model is shared broadly by most definitions and models of presence [1-9], including some of our own previous work [10].

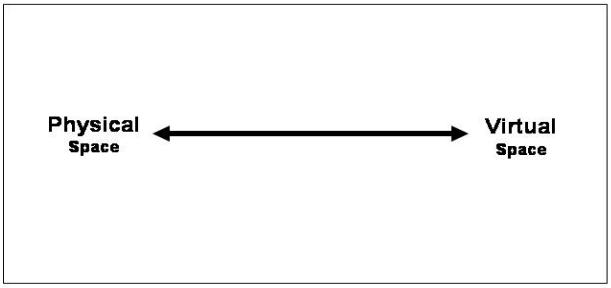

Figure 1. Inherited from early telerobotics and telepresence research, the two pole model of presence posits that presence shifts back and forth from physical space to virtual space.

The theoretical analysis below will suggest that this model may not accurately represent the actual psychological movement of presence. The two pole model may have inadverdently made it harder for presence researchers to conceptualize the process of presence shifts and the actual causes.

The two pole model also leads to three thorny theoretical problems known as the "book problem," the "physical reality problem," and the "dream state problem". These, we will suggest, are just different forms of the same problem- the failure to adequately incorporate the role of spatial attention and mental imagery in the two pole model of presence. An alternative model, the Three Pole Model [see11], may solve these problems and, possibly, provide a model that might better support presence theory and fit research findings.

1.1 Did the telepresence engineering origins of the two pole model influence the psychological assumptions of presence research?

The assumptions of the two pole psychological model of presence may have emerged from the very origins of engineering presence research in remote operated telerobotics or telepresence [e.g., 8]. In the classic telepresence engineering research, the operator of a remote telepresence system was physically removed from a remote virtually presented physical environment (see Figure 2). The assumption of the telepresence engineering model was that the goal of the system was to use sensors and effector systems and telecommunication links to "move" the user's senses and actions from the physical environment he or she was in to the remote environment transmitted to the operator via the telepresence system. The assumption of the two pole engineering model was that the key variables to increase the psychological movement of the user from the local physical environment to the remote, telepresent environment was an increase in the fidelity of the sensor and effector systems and links between the two "as if the user was actually there."

With the arrival of purely virtual environment systems, for example, training systems at NASA and immersive visualization systems, this assumption was extended to virtual environments that had no physical equivalent. In this process, an ***engineering assumption*** integral to design became calcified in part as a ***general psychological model of presence***.

The two pole psychological model imported a set of engineering design assumptions into the psychological research on presence assumptions.

Two pole assumption. The two pole model has advanced this fundamental assumption: Telepresence involves primarily an oscillation of spatial presence from

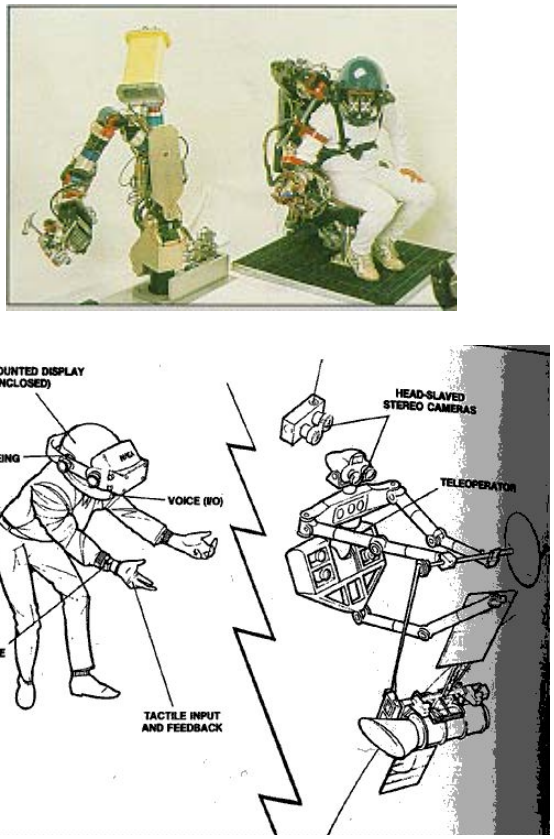

Figure 2. Example of a classic telerobotics system where the two pole model emerged. In Fisher's influential NASA diagram of telepresence, [12] the goal was to move the operator's sense of presence from the physical space he was in to the remote location of the robotic system. In this context it was logical to make the following assumptions in defining presence research:
(1) that presence oscillated between the physical and remote (virtual) environments;
(2) that interfaces that increased sensorimotor immersion were key to creating telepresence, and
(3) that increases in presence would be tied to increased performance in the remote environment.

the physical (local) to the virtual (remote) environment. This was the very logical assumption of telepresence engineering research. In articles and in measures, it was assumed that the telepresence operator could only be in one of two places, the physical local environment or the remote virtual environment [e.g., 8, 13]

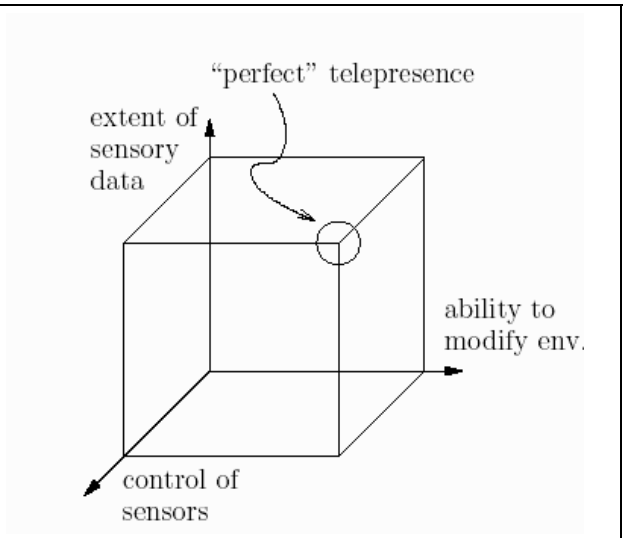

Figure 3. Sheridan's [8] influential telepresence model. It is an example of what we are calling the sensorimotor immersion assumption Three variables that characterize sensorimotor immersion are depicted as the primary causal variables for "perfect" telepresence: extent of sensory data, control of sensors, and ability to modify the environment.

The sensorimotor immersion assumption: It is logical for engineering designers of telerobotics systems to focus on the hardware interface, the development of high quality sensors and effectors and the interconnection of these [13]. When translated into psychological terms within an emerging theory of presence, the focus on interface hardware tended to advance what we call the *sensorimotor immersion assumption*. The sensorimotor immersion assumption can be seen in the influential papers by Sheridan [8] as well as others [14] (See Figure 3). The sensorimotor immersion assumption can be defined as the assumption that the primary causes of psychological presence are the immersive properties of technology. In Sheridan [8], three engineering variables can "cause" or "create" perfect presence: extent of sensory data, control of sensors, and ability to modify the environment. These can be seen as various forms of sensorimotor immersion: sensory immersion, motor immersion, and sensorimotor coordination [see 10]. The variables and criteria of telerobotics design were imported first as a cognitive model of presence shifts and of the primary psychological assumptions about what causes presence. The primary causes of presence are seen as technological.

In the engineering of telepresence and telerobotics systems it was logical to assume that by increasing the (a) level of sensory and motor immersion of the user and (b) the natural mapping of environment to action, the teleoperator would be (c) more present in the remote environment and (d) would have improved performance in the remote environment "as if he were there." And there is ample evidence that these can and do influence presence. But some researchers questioned the idea that environments and mapping needed to be natural and that presence and performance were necessarily linked [15].

Generalization of the two-pole model to a cognitive model of presence in all media.

With the rise of virtual environments in the 1990s the two pole model was generalized to all media and became a cognitive theory of presence. The generalization of the telerobotics model of "telepresence" to virtual environments is evident in Sheridan's title referring to "telepresence" and "virtual presence." The two pole psychological model of presence was further generalized to all media in much of the early literature on presence including early articles that we ourselves circulated [e.g.,16, 17]. In this process then it become less a model of telerobotics engineering, rather it became a general ***cognitive model*** of presence. Also the focus on interface variables as part of the sensorimotor assumption, became a key component of theorizing about presence.

1.2 Fundamental theoretical problems encountered by the standard two pole psychological model of presence

But even in the very formulation of the two pole psychological model of presence, there have always been anomalies that did not fit the standard two pole model well. Challenges came early to the emphasis on the sensorimotor immersion assumption that tended to be wedded to the two pole model because of its origins in telerobotics and telepresence research. These can be summarized in what I have coined as the *book problem,*

the *physical reality problem*, and finally the problem of *dream states*. These are briefly defined below.

The book problem

From the very beginning, researchers indicated that books presented an anomaly to the sensorimotor immersion assumption of the two pole model. Clearly books could create a sense of presence, but had none of the sensorimotor immersion properties that were central to the standard two pole model. The book problem can be summarized quite succinctly as follows:

> Book problem: If sensorimotor immersion is the key variable that causes presence, then how do we explain the high levels of presence people report when reading books? (see\ [18]; [19]). Books are very low fidelity, non-iconic media and are extremely low on all sensorimotor variables identified as causing presence: extent of sensory data, control of sensors, and ability to modify the environment.

The physical reality or real world problem

The physical reality or real world problem is the companion to the book problem. Previously I defined the physical reality problem as follows:

> Physical reality problem. If sensorimotor immersion is the necessary and sufficient cause of presence, then why do people sometimes not feel present in physical reality which defines the criterion (see \ [20]) for the maximum level of sensorimotor immersion? People daydream, are not engaged, and drift away in normal physical environments.

The physical reality problem leads to questions as to where people are phenomenologically present if not in the physical environment. Where are they present? We return to this issue below.

The problem of presence in dream states

And finally, there is a related problem. Where do dream states fit in the two pole model of presence?

> Problem of dream states. In dream states, individuals may experience very high states of presence, but they are not present in the room, the physical location that their body is located, nor are they present in any mediated environment. Where are they present?

It has been claimed that in a very loose sense a dream is a "virtual environment" (see for example \ [21]). But this claim is unsatisfactory and is not neatly accommodated by the two pole model. Clearly a dream has no or little sensorimotor immersion. The psychological mechanisms that generate presence in a dream state have to be at least slightly different than psychological mechanisms that generate presence in an immersive, 3D multimodal virtual environment.

Are these problems just different faces of one problem for the two pole model?

It is possible that these three problems may be just different faces of the same problem, a failure of the two pole model to satisfactorily represent the actual movement of presence. All three problems may be related to the failure of the two pole model to adequately incorporate the role of spatial attention and mental imagery in shifts in presence. As we will argue below, there are actually two key processes that drive presence and these are potentially confused and conflated or not fully represented in the standard two pole model of presence.

2. Evolutionary primacy in a theory of shifts presence: Should a theory of presence explain how shifts in presence predate all media and occur without any medium?

Let us start by first considering presence from an evolutionary viewpoint. Shifts in presence probably predate the arrival of all media. As a psychological process, the ability to shift ones sense of spatial presence was not created for virtual environments. Clearly, the ability to shift ones spatial presence must be based on mechanisms that most likely served some evolutionary value. We can conceive of situations when our ancestors needed to phenomenally experience presence in a place other than the one the body was located, for example in action planning. Furthermore, the mental image of oneself in another place may have been critical to the emergence of representation and self-consciousness [22]. Viewed within a evolutionary time frame, virtual environments, in fact all media, appear very late, but somehow activate and leverage mechanisms that existed not to serve any particular medium, but, possibly, all representation.

Therefore, a cognitive theory of shifts in presence should fit this longer evolutionary view of presence, what

I will call pre-media evolutionary primacy, or *evolutionary primacy*, for short. The notion of a pre-media evolutionary primacy of presence is easy to accept, but doing so warrants certain conclusions. Conclusions warranted by the notion of evolutionary primacy,

1. If shifts in presence predate media, then we should be able to explain the shifts of presence without any reference to a medium. Cognitive processes that initiate presence shifts must serve cognitive functions that are independent of media

2. All representation must engage the processes activating a presence shift, although they may do so with different strength and with slightly different mechanisms.

If we look at the conceptualization of presence and current research on presence, especially at the components that drive presence, there may be the basis for an alternative model.

3. The Three Pole Model of Presence Shifts

The Three Pole Model of Presence Shifts has been created to explain presence data and to overcome theoretical problems associated with the presence conceptualizations found in the standard two pole model of presence. Below we introduce an outline of the model. See Biocca [11] for a more complete discussion of psychological research guiding the model.

In the Three Pole Model of Presence, a new third pole of presence is added to the standard two poles of presence shifts, a pole called mental imagery space. Spatial models generated by mental imagery have similar analog properties of sensorimotor spaces and appear to make use of neural mechanisms associated with visual and other sensory spatial processes [23-25]. The model proposes that spatial presence shifts among three dynamic sources of spatial cues: physical space, virtual space, and, finally, a mental imagery space. At any point in time, users of medium are constructing a simulation, a mental model of the space around their body. This model of egocentric space is constructed from sensory cues and memory. A quasi-triangular space defined in the graphic model by three poles (see Figure 4) represents the range of possible spatial mental models that are the specific locus of an individual user's spatial presence.

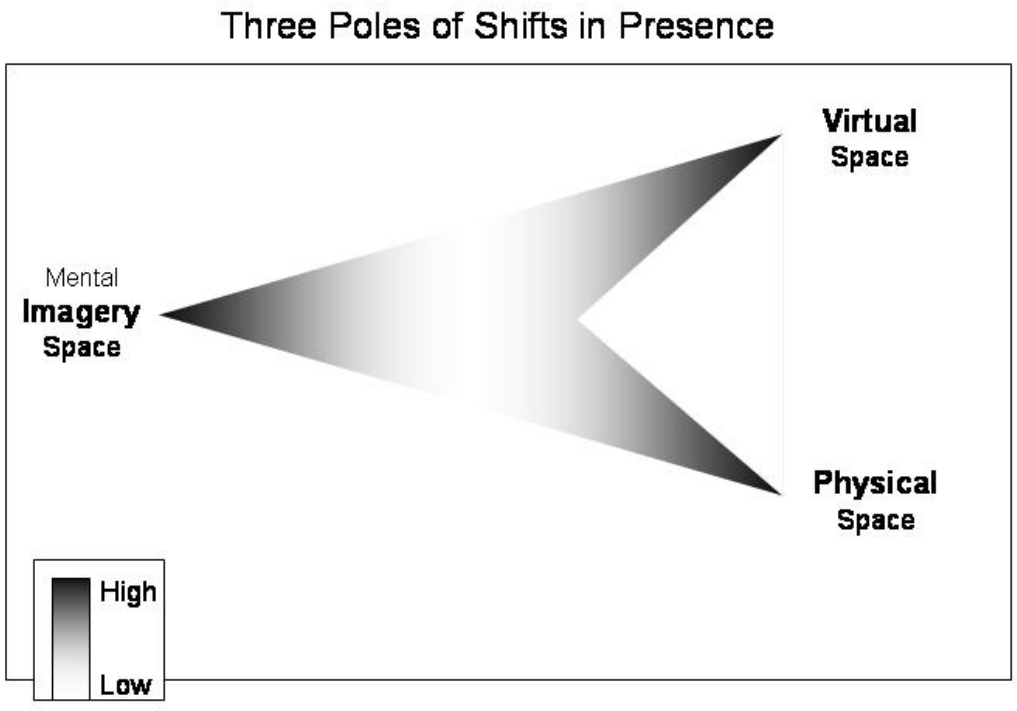

Figure 4. In the three pole model a media user's spatial presence is conceived as shifting among three poles: physical space, virtual space, and mental imagery space. For any user spatial presence will "gravitate" towards one of the poles, i.e., one of three dynamic sources of spatial cues will dominate in the formation of the user's mental model of egocentric space.

Finally, the user's spatial presence will tend to "gravitate" to one of the three poles. To put it another way, the mental model of space that defines a user's spatial presence will be dominated by spatial cues from one

of the three spaces, but cues from other spaces, especially mental imagery space, may be merged, or distort, or conflict properties of the user's mental model of the space. The mental model of space is dynamic and continuously updated.

Spatial attention and spatial updating

What then regulates shifts in presence among the three poles of presence? The model proposed that there are two axes to shifts in presence defined by dominant cognitive processes: one triggered by spatial attention and the other by spatial updating. Attention has a spatial component that selects and focuses conscious processing on stimuli based on spatial cues. Attention can be divided across space. The locus of attention can be driven by user's goals or by salient changes in the environment.

Spatial attention may dominate in shifting spatial presence between imagery space and any bottom up, sensory driven space be it virtual space or physical space. Support for the role of attention comes from presence measurement where the presence of dimensions labeled as "attention" suggests a role for this process [7, 26, 27]. Shifts in presence due to spatial attention might be triggered by top down processes driven by user's goals, motivation, and content or by bottom up processes such as sudden changes in the environment.

The second class of shifts in presence may be triggered by automatic spatial updating which primarily influences the shifts in presence between physical space and virtual space especially with immersive iconic media. Sensory cues accompany body movement from one space to another. Changing the model of the environment and keeping track of the many objects in space around the body is a largely effortless unconscious process. *Spatial updating* is the term used to describe the processes that automatically changes or updates the internal mental model of the location of objects in the environment relative to the body following a movement of the body. It is a largely sensory driven, so-called "bottom up" cognitive process. The process is largely unconscious and makes little use of conscious attentional processes.

Spatial updating may trigger shifts in presence in response to changes in the stimuli that signal

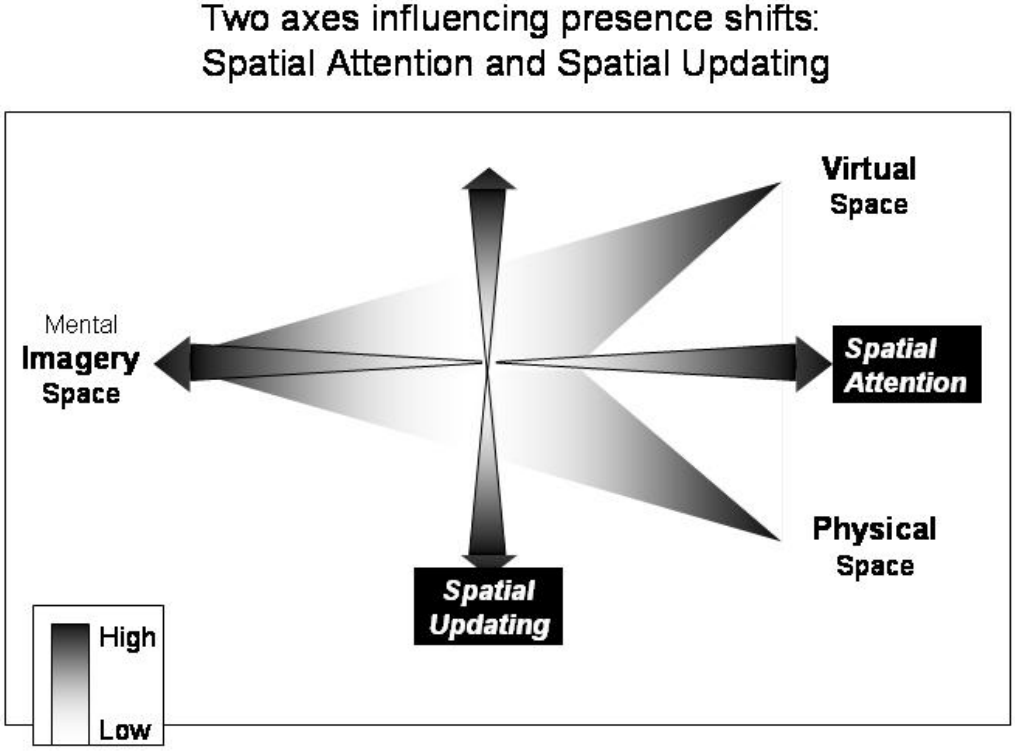

Figure 5. The Three Pole Model proposes that there are *two axes* to shifts in presence defined by dominant cognitive processes: one triggered by spatial attention and the other by spatial updating. *Spatial attention* may dominate in shifting spatial presence between imagery space and any bottom up, sensory-driven space be it virtual space or physical space. The second class of shifts in presence may be triggered by automatic *spatial updating* which primarily influences the shifts in presence between physical space and virtual space, especially with immersive iconic media. These two mechanisms represented as axes in the graphic model, operate at all times, but make use of slightly different cognitive mechanisms to influence shifts in presence.

movement of the body such as sensorimotor integration or changes in the optical flow [See 11].

These two mechanisms represented as axes in the model below operate at all times, but make use of slightly different cognitive mechanisms to influence shifts in presence.

When is presence low or divided?

The Three Pole Model of Presence Shifts suggests an approach to the problem of oscillating or divided presence. Following the research on whether attention could be divided or not, the Three Pole Model posits a state of divided sensorimotor or spatial attention. These are cases where presence in any one pole or location may be distributed across imagery space and either physical or virtual space. Consider the examples of day dreaming or mindless driving; cases where attention is divided between mental imagery space and physical space [see 11]. Using the spatial properties of the graphic model, we will refer to these cases as the **zone of low divided presence.** When measured with self report measures or measures of "breaks" in presence, these will show up as low presence, but the breaks or oscillation can not be just between virtual and physical space but more likely between imagery space and the others. Under conditions when spatial attention is divided or oscillating across more than one location, individuals will report or experience *low presence in any specific space*.

At the opposite end of low divided and oscillating presence, the Three Pole Model posits conditions for high presence. Within the graphic model this is seen as the zone of high or undivided presence where one's spatial model must be dominated by either physical space or virtual space. As spatial attention increases, an individual may not have the mental resources to maintain different spatial mental models of high resolution. Under conditions where action in space involves high spatial attention to sensory stimuli (e.g., learning a new motor task or during fight-or-flight), spatial presence is focused and undivided on one consistent spatial model driven by physical or virtual space. In these cases individuals may report being in a state of high, undivided presence.

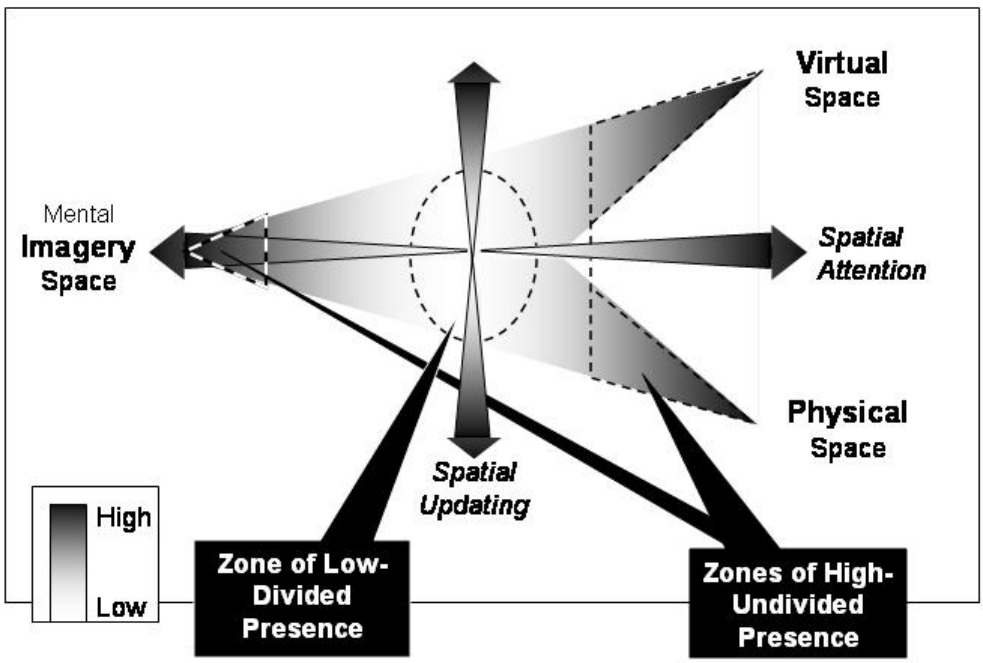

Figure 6. Can spatial presence be divided across two spaces? Or is only one spatial mental model possible at one time, therefore presence can only oscillate from one to the other? The Three Pole Model suggests that both are true under different conditions. A zone of low-divided presence is theorized to exist when spatial attention is low and divided between an internally driven mental imagery space and a sensory driven physical or virtual space (e.g., day dreaming). Under conditions where action in space involves high spatial attention to sensory stimuli (e.g., learning a new motor task or during fight-or-flight), spatial presence is focused and undivided on one consistent spatial model driven by physical or virtual space. The only case of high-undivided spatial presence in imagery space is dreaming, where most sensorimotor input is suppressed or incorporated into the imagery space.

In summary, the model posits that spatial attention and spatial

updating, spatial cognitive processes that are independent of any representational system, drive shifts in presence that dynamically shift among memory and sensory spatial cues from three poles: imagery space, physical space, and virtual space. Furthermore, that oscillation between mental imagery and the other spaces may be the dominant axis of presence shifts. It predates any medium and may be essential to representation. Finally, presence shifts driven by spatial updating may respond unconsciously to broad shifts in sensory inflow and therefore are highly responsive to immersive interfaces.

4. How the Three Pole Model of Presence resolves the book, physical reality, and dream problem.

We stated earlier that the two pole model of presence came with certain challenges that we labeled the book problem, the physical reality problem, and the dream state problem. As we suggested above, these are really three different faces of the same problem, the inability to accommodate the third spatial pole of presence. These problems are more easily explained within the Three Pole Model.

4.1 Possible resolution of the physical reality problem

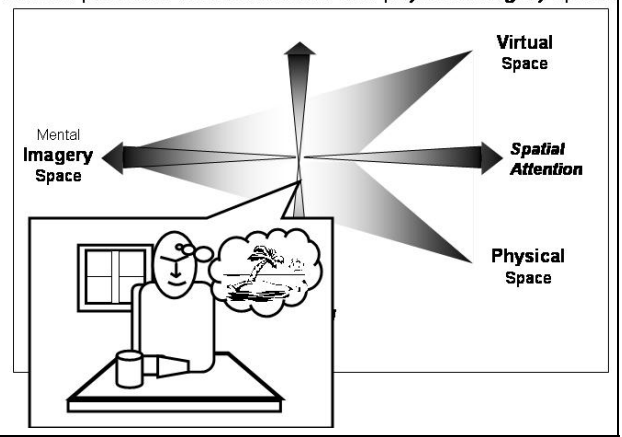

Figure 7.

How then is it, that under conditions of high sensory fidelity in the physical environment, people do not feel present? The two pole model of presence tended to be committed to the *sensorimotor immersion assumption* that if virtual environments simply provided the high sensory cues of physical environments, users would experience high levels of presence. But the physical reality problem has been a challenge to that engineering assumption. It suggested that this would not be true in all cases. A high level of sensorimotor immersion was not a necessary or sufficient condition for presence. Why?

The answer is suggested by the cognitive forces associated with the Three Pole Model, especially the spatial attention axis. Tasks and environments can place high or low demands on spatial attention. For example, learning to ride a bicycle may be highly demanding of attention compared to sitting stationary with no current task may be less demanding. In cases where the physical environment is not demanding of spatial attentionindividuals may experience low spatial attention to the physical environment and become disengaged. A mental imagery space may dominate leading to an oscillation or division of presence across two spatial models the physical and the imagery space. The phenomenal experience reported in self-report measures will be of low physical presence.

4.2 Possible resolution to the dream state problem

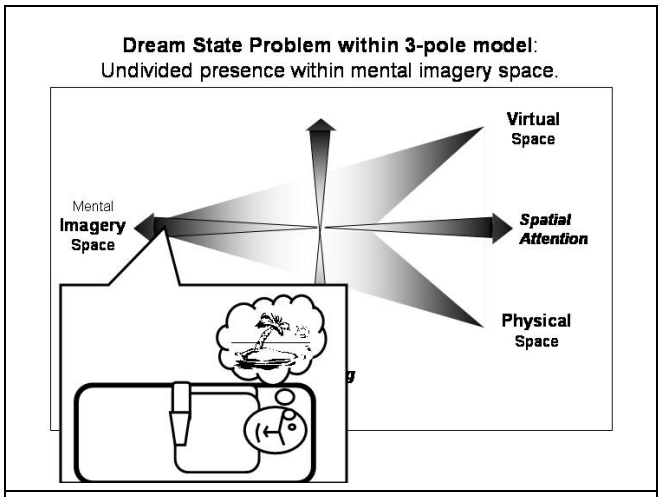

Figure 8.

The model suggests that the dream state is not just another form of "virtual space." Rather, dream states involve little input and attention to sensorimotor cues. There is little bottom up processing of sensory cues other than random activation from the brain stem. The dream state is the purest and highest form of imagery space. Clearly, when the individual is in a dream state, the spatial model of imagery space has only marginal

relationship to spatial properties of physical space or virtual space surrounding the user's body.

Nonetheless, dream states are not completely divorced from sensorimotor cues. There can be "leakage" from virtual spaces and physical space into the dream state. For example, wind blowing across the face from an open window might be incorporated into a dream of sailing. Or when falling asleep in front of a television set properties of the television sound or voice might be incorporated into the imagery space. Nonetheless, in both cases, the "leakage" across spaces is not likely to fundamentally alter the egocentric spatial model that drives the presence of the user in the imagery space.

4.3 Possible solution to the book problem

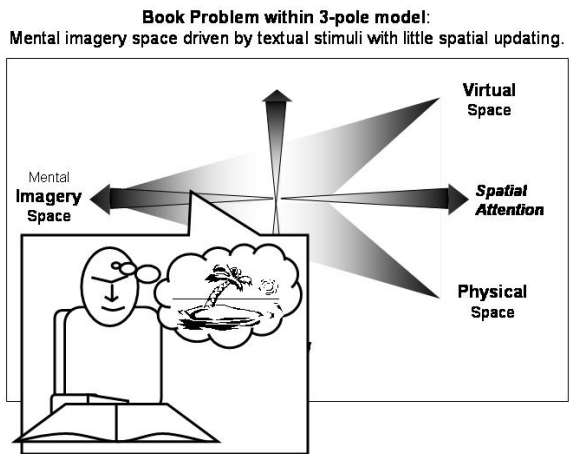

Figure 9.

The Three Pole Model can deal with what may be the thorniest challenge, the book problem. How is it that individuals report high levels of presence with books when these are very low fidelity, non-iconic media? We posit that books achieve their levels of presence by making heavy use of the imagery space to "fill in" the spatial model cued by the book.

The details of the egocentric spatial model generated by the book are generated largely from memory. So in some ways, the presence of books contains components of the virtual space and imagery space, but unlike an immersive 3D virtual environment, there is a higher component of imagery space.

How might we distinguish the properties of a book driven imagery space from an immersive VR space? This very interesting question may tell us a lot about presence. We suggest the following theoretical propositions: Spaces generated from mental imagery may not have as much: (a) sensory resolution, (b) salience in memory, (c) intersubjective consistency as those generated from an actual space.

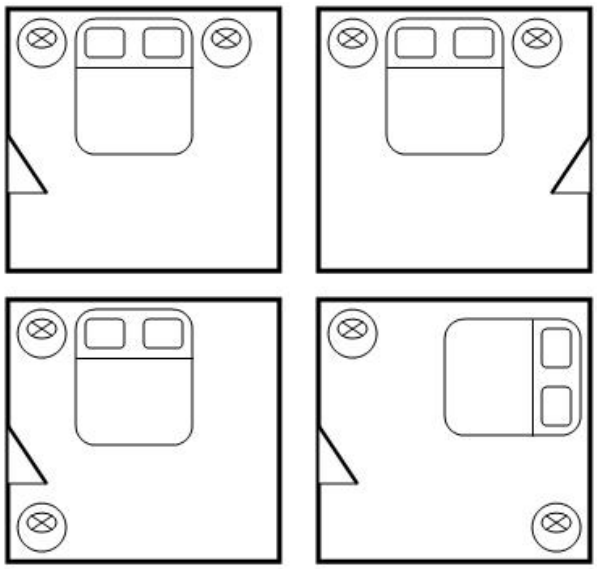

Figure 10. Demonstration of intersubjective inconsistencies in text-driven imagery space. Four of many possible room layouts potentially imaged from the following story: "Mary entered the dark hotel room. She turned towards the bed. There were two small tables with lamps. She bent down to turn on one of the lamps."

4.4 Demonstration of text generated intersubjective inconsistencies in book-driven, imagery space.

Secondly, we would predict that memory for details and objects of imagery spaces generated from a book may differ more significantly across users than an experience in virtual environment because they make much heavier use of memory resources to construct the space dominated by imagery. For example, consider the following text:

> Mary entered the dark hotel room. She turned towards the bed. There were two small tables with lamps. She bent down to turn on one of the lamps.

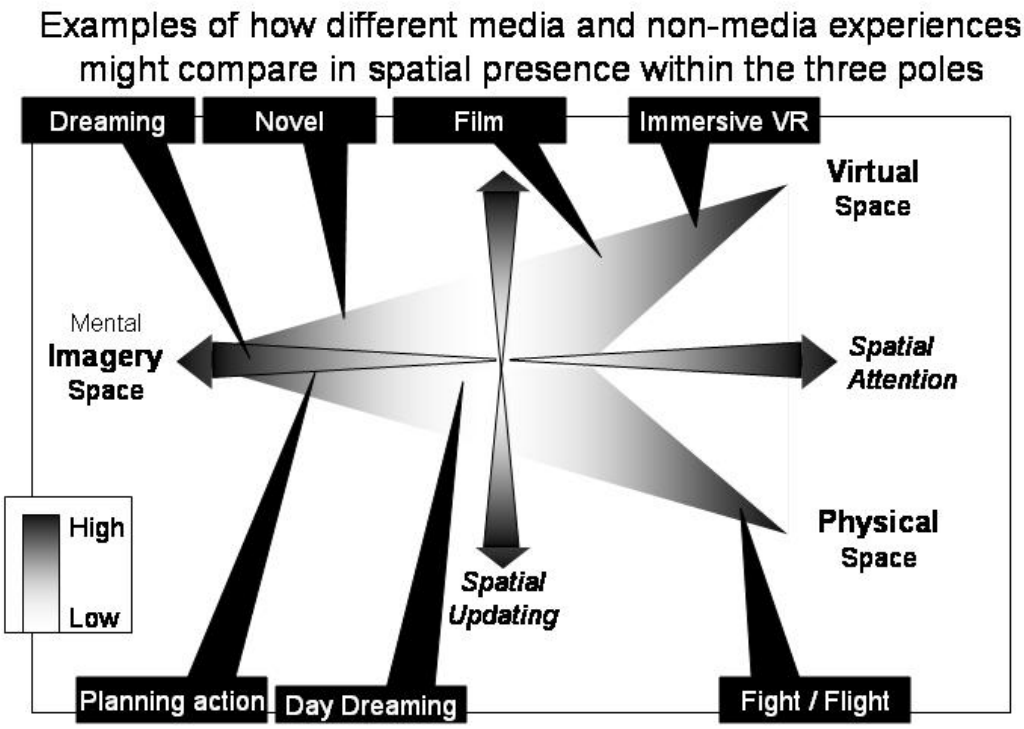

Figure 11. Examples of how media and non-media experience might differ in their relative use of spatial cues within the three poles. (Note that the three pole model does not assume a fixed position for any medium, but that presence will fluctuate with content and context.)

In a text version this might generate very different but incommensurate egocentric spatial models in users. For example, where is the door in relationship to the user? The text says she turned. Did she turn left or right? The text says there were two small tables with lamps. What is their position relative to the bed? Consider the models in Figure 10. Any one of these models as well as many other possible spatial layouts is consistent with the text and could be created in the imagery space of the reader.

Finally, there are a number of unspecified variables in the text that would be immediately retrievable from those who experience the virtual environment such as the color of the walls, whether there is a window, etc.

Therefore, the egocentric spatial model generated by books may be far more variable across users and have less spatial resolution, as measured by retrievable details from the scene, and less intersubjective consistency, as measured by level of consistency across individuals. Like dream spaces and other imagery spaces, the sense of presence can be strong, but on average it may not be possible to generate and maintain the level of presence experienced in physical or iconic virtual environments from symbolic environments or imagery states alone.

The location of different media presence experiences within the Three Pole Model

Spatial presence during the use of any medium may be driven by input from any one of the three poles of presence, but to a large part by a blend of the memory driven processes of mental imagery and the sensory driven poles of physical space. Using the Three Pole Model, we can generate a map of the loci of types of media and other experiences. We have created such a hypothetical map in Figure 8. Various types of spatial information processing may be driven by different blends of input from the three poles of presence. The most important to presence researchers are those situations where the user is driven by high levels of spatial

attention and spatial updating. In physical space the behaviors associated with fight or flight responses to objects or beings in the environment are likely to be instances of very high presence. When such highly arousing responses are triggered in virtual immersive environments, for example, the virtual pit demonstration at UNC, we see high levels of arousal and presence, as measured by both physiological and self-report measures. Novels may involve a blend of spatial cues from virtual and mental imagery space. Situations of divided presence such as those captured by the phrase "day dreaming"

may be instances of low presence, where presence is divided or oscillating between mental imagery space and the other two poles of presence. Iconic media, especially those that use full body movement such as immersive VR, may trigger spatial updating mechanisms and shift presence towards spatial cues from virtual space.

5. Summary of the Three Pole Model of Presence

We began by showing how presence research may have inherited what we called the two pole model of presence from its origins in telerobotics and telepresence research. A logical engineering model of the problem of presence became a physical model of presence shifts. Psychological theories based on the two pole model have been troubled by an inability to resolve theoretical and observational inconsistencies such as those labeled the book problem, the physical reality problem, and the dream state problem. We suggested that these problems are just three faces of one problem, the failure of the two pole model to adequately incorporate the roles of mental imagery and spatial attention in driving presence.

The Three Pole Model of Presence offers a parsimonious explanation for both the changing loci of presence and the mechanisms driving presence shifts. Compared to the standard two pole models, the Three Pole Model appears better able to resolve the logical and observational challenges summarized in the book, the physical reality, and the dream state problems. Once a third pole, mental imagery space, is added,we see that the book, the physical reality, and the dream state problems may be just different situations involving shifts of presence to mental imagery space and a withdrawal of attention from sensorimotor stimuli. The Three Pole Model may have implications for models of the causes of presence and the measurement of presence [11].

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