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EVALUATING IMPACT OF NAVIGABILITY AFFORDANCES AND
NARRATIVE TRANSPORTATION ON SPATIAL PRESENCE

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ABSTRACT

With advances in technology, mediated environments—especially video games—are increasingly designed around the metaphor of space. Today, media interfaces provide a variety of tools and affordances for users can interact with and freely navigate these mediated cyberspaces. Users of these new media often forget their immediate physical surroundings and experience a sense of “being there” in the mediated environment. This idea of “being there”, referred to as the sense of presence, has received much attention from scholars from diverse disciplines. However, the exact mechanism of its formation is still not understood and hardly any research has systematically approached spatial presence formation as a function of navigability—a key affordance of new media.

The present study examines spatial presence formation as a function of navigability affordances to fill this gap in literature. To this end, the study begins by explicating the concept of navigability to define it as well as identify its components. The concept of spatial presence is explicated to clarify its meaning, define the boundaries of its meaning and to identify factors affecting it. After explicating the two key concepts, various theoretical mechanisms by which navigability components affect spatial presence are discussed and specific hypotheses proposed. The impact of navigability on spatial presence is examined through a controlled experiment (N=240) in a large screen, passive stereo virtual reality display. Narrative transportation is added as a user-centric variable in the experiment to examine whether user-centric characteristics can compensate for, or interact with technology affordances. Findings reveal that steering control, which affords locomotion through the virtual environment, is a strong predictor of spatial presence with greater steering control and maneuverability leading to greater spatial presence. Contrary to expectation, narrative transportation had a negative impact on spatial presence. Findings indicate support for heuristic processing of spatial cues and revealed capacity limitations in processing spatial cues. The study also revealed boundary conditions for the role of spatial situation models in formation of spatial presence.

Theoretical and practical implications of these findings are discussed.
TABLE OF CONTENTS

List of Tables ......................................................................................................................... v
List of Figures ......................................................................................................................... vi
Acknowledgements ................................................................................................................... vii

INTRODUCTION ....................................................................................................................... 1

Chapter 1.  REVIEW OF LITERATURE & HYPOTHESES .................................................. 3
  Explicating navigability ......................................................................................................... 4
  Spatial presence, explicated ............................................................................................... 12
  Navigability and spatial presence ...................................................................................... 20

Chapter 2.  RESEARCH METHODS ...................................................................................... 36
  Experiment design .............................................................................................................. 36
  Experiment setting ............................................................................................................. 37
  Stimulus details .................................................................................................................. 38
  Independent variables, their operationalization and implementation ......................... 40
  Procedure ........................................................................................................................... 53

Chapter 3.  DATA ANALYSIS AND RESULTS ....................................................................... 58
  Hypotheses set – I : IVs and Spatial presence ................................................................. 61
  Hypotheses set – II : IVs and Spatial situation model .................................................... 66
  Hypotheses set – III : Spatial situation model and spatial presence ......................... 68
  Testing for SSM mediating spatial presence .................................................................... 72
  Supplementary analysis .................................................................................................... 73

Chapter 4.  DISCUSSION ........................................................................................................ 76
  Interpretation of findings ................................................................................................. 77
  Theoretical implications .................................................................................................. 84
  Methodological implications ......................................................................................... 88
  Practical implications ..................................................................................................... 89
  Limitations ....................................................................................................................... 92
  Directions for future research ...................................................................................... 94
  Conclusion ....................................................................................................................... 96

REFERENCES ......................................................................................................................... 98

Appendix – A  Questionnaire .................................................................................................. 110
Appendix – B  Experiment protocol and script for verbal instructions ................................ 126
Appendix – C  Opening screens for narrative transportation ............................................. 132
Appendix – D  Details and screen shots of office environment virtual reality model ....... 137
List of Tables

Table 1.  Distribution of participants across experimental conditions.......................... 54
Table 2.  Bivariate correlations among spatial presence scales..................................... 58
Table 3.  Descriptive statistics for dependent, mediating and control variables............. 59
Table 4.  SSM and spatial presence – Self location......................................................... 69
Table 5.  SSM and spatial presence - Possibilities for action.......................................... 70
Table 6.  SSM and spatial presence - Vection ................................................................. 70
Table 7.  SSM and spatial presence - Reality judgment.................................................... 71
Table 8.  Spatial presence dimensions predicting enjoyment............................................ 73
List of Figures

Figure 1. Navigation components ................................................................. 6
Figure 2. Taxonomy of virtual travel techniques ........................................ 8
Figure 3. Taxonomy of virtual travel techniques based on level of user control ....... 8
Figure 4. Navigability components ................................................................. 9
Figure 5. Guidance system using 3-d arrows to known landmarks .................. 11
Figure 6. Summary of navigability explication ............................................. 12
Figure 7. Presence typologies ................................................................. 13
Figure 8. Hypothesis H_{12}: Interactive effect of steering control and constraints .......... 25
Figure 9. Hypothesis Set – I: Navigability affordances and spatial presence .......... 29
Figure 10. Hypothesis Set – II: Navigability, narrative transportation and SSM .......... 33
Figure 11. Overall mapping of hypotheses ...................................................... 34
Figure 12. Stimulus presentation in the IEL .................................................. 38
Figure 13. Image of the virtual reality office environment interior ................. 39
Figure 14. Joystick controls in the high steering control condition ............... 41
Figure 15. Joystick controls in the low steering control condition ............... 41
Figure 16. Image of dashboard in the high guidance condition ..................... 44
Figure 17. Image of dashboard in the low guidance condition ..................... 45
Figure 18. Screen shot of puzzle task for measuring SSM .......................... 56
Figure 19. Spatial presence - Reality judgment: Guidance x steering control interaction ...... 63
Figure 20. Spatial presence - Reality judgment: Narrative x steering control interaction ...... 64
Figure 21. Summary of spatial presence results ............................................. 65
Figure 22. Impact of guidance and narrative transportation on SSM ................ 67
Figure 23. Summary of spatial situation model results .................................... 68
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Introduction

Ever since Gibson (1984) coined the famous term ‘cyberspace’ in his novel *Neuromancer*, it has been applied as a metaphor to digital media, from the World Wide Web to virtual reality. Advancements made in computer graphics technology, both in terms of hardware and software, have made mediated environments like video games highly spatialized and interactive. Electronic media from simple hypertext to immersive virtual reality systems are increasingly designed around the metaphor of space. They are conceptualized and realized as venues to be experienced and spaces to be explored.

Adoption of a spatial metaphor implies that media environments are best experienced through exploration. Far from the days when media were seen as a mode for one-way transmission of information, the user can today interact with and freely navigate these mediated spaces. This is relevant irrespective of whether the context is e-commerce, entertainment media such as games and role-playing environments or online communities such as SecondLife™. A variety of user interface devices present today’s user with opportunities to immerse oneself as well as act in these virtual environments, leading them to forget their immediate surroundings and experience a sense of “being there” in the mediated environment. This subjective experience of ‘being there’ in a mediated environment is referred to by media scholars as presence (Lombard & Ditton, 1997) and is considered to be an important factor for media enjoyment (Klimmt & Vorderer, 2003).

The main goal of this dissertation is to improve our understanding of how navigational affordances enhance spatial presence, which is one among many types of presence. This dissertation aims to improve our theoretical understanding of spatial presence formation. The study explores spatial presence mechanisms within the context of navigation in 3-dimensional worlds. The context of 3-dimensional navigation is chosen since
it provides a context to examine both immersion and activity-based theories of spatial presence. Other media such as movie clips or print-based media do not provide opportunities to explore activity-based approaches to spatial presence. Based on the findings, this study also outlines practical implications for developing a wide variety of navigable spatial environments from games to immersive virtual reality simulations. The dissertation is organized as follows.

In chapter 1, the dissertation begins by explicating the concepts of navigability and spatial presence, which are central to the research question. Based on literature review, specific hypothesis regarding spatial presence formation as function of navigability affordances are proposed. Chapter 2 details the experimental design, operationalization of the independent variables and their implementation in a virtual reality environment. The experimental settings in the Immersive Environments Lab, specifics of participants, procedures as well as measures for the dependent and control variables are also described. Chapter 3 describes the data analysis procedures, results pertaining to specific hypothesis and their interpretations. Chapter 4 discusses the findings and their theoretical, practical and methodological implications. Limitations of the current study and directions for future studies are also laid out.
This chapter reviews relevant literature and explicates navigability and spatial presence, two main concepts explored in the study. Each explication has a slightly different objective and thus follows a somewhat different strategy. Navigation in a mediated environment, whether it be hypertext or immersive virtual reality, is a function of the user. Navigability, which is the affordance for navigation on the other hand, is resident in the technology (Sundar, 2008). The focus here is to enhance our theoretical understanding of how navigability affordances affect spatial presence. Therefore, in explicating navigability, we begin by understanding the conceptual dimensions of navigation and then recasting them into their respective affordances. These affordances can then be manipulated through the user interface features and input devices in a controlled experiment and their impact on spatial presence measured. In explicating spatial presence, the objective is to refine its theoretical definition, identify its dimensions and operationalize it for measurement.

There are two approaches for explicating the meaning of a concept – by distillation or by list (Chaffee, 1991). While meaning analysis for most concepts are carried out through the process of distillation, some concepts such as mass media are usually defined by list. The human-computer interaction (HCI) discipline also relies heavily on taxonomies for studying how different interface features impact task performance differently. However, as Chaffee (1991) points out, definition by list poses two important challenges – one of specifying the rules followed in building the list and the problem of whether an innovation would belong to the list for lack of further definition. To overcome these, he suggests building a list after explication.

While explication of spatial presence is approached via distillation, a slightly different strategy was adopted for explicating navigation in virtual environments. As a first step, the concept of navigation is explicated by identifying various definitions and a meaning analysis
carried out. Once the concept of navigation is understood and its key dimensions identified, this would define the criteria for inclusion of a tool as a navigational device as well as for mapping it along the corresponding dimension of the concept. This can be the starting point for the taxonomy, and sub-classifications can then be mapped based on criteria such as affordances.

**Explicating navigability**

*Navigation*

Navigation, originally studied within the context of seafaring, received a resurgence in the domain of architecture and urban design with the work of Lynch (1960). With advances in computing and the increase in complexity of the electronic world, irrespective of whether they are conceived as immersive virtual reality, hypertext or visualizations of abstract data, navigation is again in the spotlight. Studies concerning navigation, irrespective of the context, often share the goal of ‘avoiding getting lost’ and explore strategies, techniques and tools, which help to attain that goal.

**Explicating navigation**

*Preliminary definition*

Oxford English dictionary pointing to the word’s Latin roots refers to navigation as the art of driving or steering the ship (Coventry, 1999). Navigation is broadly defined as the ability of humans and animals to find their way and move from one point to another (Pick, 2001). Here knowledge of one’s starting and finishing points, awareness about potential paths and progress during the movement are envisioned as pre-requisites. Since the preliminary definition indicates a behavioral as well as psychological component, navigation is conceptualized in this study as a variable that can be affected by individual differences and skill as well as environmental factors.
Literature review

An early attempt to achieve semantic clarity regarding the concept of navigation in electronic worlds was during the workshop at the annual conference of the Association for Computing Machinery’s special interest group in Computer-Human Interaction in 1997. Jul and Furnas (1997) note that the initial observation at the CHI’97 workshop on navigation was that the term meant different things to different people and they list a diverse set of conceptualizations among the workshop participants. These were then used as starting point to reconceptualize navigation. Jul and Furnas (1997, p.1) define navigation as the process “whereby people determine where they are, where everything else is, and how to get to particular objects or places.” Navigation is conceptualized by Jul and Furnas (1997) as an incremental real-time process that integrates components of locomotion and decision-making.

Herndon, van Dam and Gleicher (1994, p. 38) define navigation slightly differently as “the planning and execution of travel through space, real or virtual, carried out with reference to external or internal representations of the space being traveled”. They classify navigation into three types - based on which kinematic order is relied upon for updating position and orientation. Piloting is position based and depends on external signals for identifying the position and orientation of the user whereas dead-reckoning is velocity based (Herndon et al., 1994). Hutchins (1995) uses the term piloting interchangeably with navigation. The third type, referred by Herndon et al. (1994) as “inertial navigation”, integrates the linear and rotary accelerations of the user to ascertain linear and rotary displacements with respect to the starting point. In these definitions navigation is seen from a more biological perspective than a cognitive one.

Downs and Stea (1973) describe navigation as a four-part sequential process beginning with orienting, followed by choice of the correct route, monitoring the chosen route and recognizing the goal when it is reached. Czerwinski (cited in Jul & Furnas, 1997, p.4) distinguishes between situation-based and plan-based navigation. The former is reactive in
nature, relying on landmarks and situation specific knowledge where as the latter relies on survey knowledge resulting from an advance plan to reach the goal (Jul & Furnas, 1997).

Overall, the definitions of navigation suggest that navigation involves both the physical act of movement and the cognitive act of deciding where to go. Scholars like Hochmair and Luttich (2006) treat navigation and wayfinding as independent processes. Wayfinding according to Hochmair and Luttich (2006, p. 246) is “choosing appropriate path segments from an existing path network and following the route created by that path” whereas navigation refers to the “process of following a given course in an open space”. However, there is general agreement in the literature that the two process are interdependent. Bowman, Johnson and Hodges (1999) as well as Darken and Peterson (2001) have defined navigation as consisting of complementary components - wayfinding which is the cognitive component that guides movement and travel or locomotion which is the motor component. The two components are interdependent and most cases of navigation involve both locomotion and wayfinding, though probably to different degrees. Here wayfinding is considered as a sub-concept of navigation. This breakdown of navigation is illustrated below in figure – 1.

![Diagram of Navigation Components](image)

**Figure – 1** Navigation Components

*Navigation in virtual environments*

Navigation is an important aspect of interacting with 3-dimensional (3-d) environments, especially immersive environments. Navigation research in 3-d interfaces also show a clear distinction between travel and wayfinding. However, most of the research
involving 3-d user interface and virtual reality (VR) research is focused on design and usability as opposed to theory building. During the early days of 3-d graphics, the research focus was on techniques for movement within VR and computer generated 3-d environments. As 3-d computer graphics became increasingly sophisticated and virtual environments more complex, the feeling of ‘getting lost’ became commonplace. This is more pronounced in virtual reality since the non-visual cues, especially kinesthetic ones are usually absent. This prompted a new wave of research to design way-finding aids for 3d environments. Next sections discuss how travel and wayfinding are conceptualized in virtual environments and list various taxonomies for travel and wayfinding. Based on analysis of these taxonomies, broad operationalizations of travel and wayfinding tools techniques are discussed.

Travel in virtual environments

According to Bowman, Koller and Hodges (1997), travel in a 3-d environment is the basic task of moving the user viewpoint from one location to another. Tan, Robertson and Czerwinski (2001) adds more specificity by defining travel as viewpoint motion specified by position, orientation and speed of virtual camera. Bowman, Kruijff, LaViola, and Poupyrev (2005) review four schemes that attempt to classify and categorize travel techniques (p. 189-191):

• Active versus passive techniques depending on whether the user or the system is in control of the movement of the viewpoint
• Physical versus virtual techniques depending on whether the movement is based on the whole body movement of the user
• Classification using task decomposition
• Classification using metaphor

From the above schemes, classifications based on task decomposition (Bowman et al., 1997) or level of user control (Bowman, Davis, Hodges, & Badre, 1999) illustrated below
have a greater granularity and covers most, if not all of the design space for travel techniques.

![Taxonomy of virtual travel techniques](image1)

*Figure – 2 Taxonomy of virtual travel techniques*
*Source: Bowman, Koller, & Hodges (1997, p.46)*

![Taxonomy of virtual travel techniques based on level of user control](image2)

*Figure – 3 Taxonomy of virtual travel techniques based on level of user control*
*Source: Bowman, Davis, Hodges and Badre (1999, p. 620)*

**Navigability – Affordance for navigation**

Earlier sections defined navigation and identified travel and wayfinding as its components. Having identified the components of navigation, it is important to recast it in terms of its affordance, i.e. navigability. Following Sundar’s (2004) approach to theorizing interactivity, navigability here is also seen as an attribute of the technology (thus building theories of media) rather than as an attribute of the user (which builds theories of psychology). This section elaborates the taxonomy further by recasting travel and
wayfinding in virtual environments in terms of their affordances - traversibility and guidance respectively. Figure – 4 illustrates the breakdown of navigability affordances.

Figure – 4  Navigability components

*Traversability and guidance*

Traversability is defined as the affordance to move larger distances in a virtual environment resulting from environmental constraints, i.e. constraints imposed by the environment as well as the extent of user control for steering. Environmental constraints in the context of virtual environments arise from the combination of constraints imposed by the environment on direction and orientation of movement as well as physicality analogous to the real world such as gravity and collision detection. Environmental constraints are global in nature in the sense that they are consistent across the virtual environment. For example, the gravity constraint will anchor the user movement in the virtual environment to the nearest horizontal plane. Technically, this is implemented by limiting the user movement along the vertical axis to a certain height in the virtual environment.

Steering control refers to the choices available to the user at any given point while moving through the virtual environment with respect to direction of translational movement, choice of axis for rotational movement and velocity. In simple terms, it is the maneuverability to follow a desired path in the environment. One way to operationalize travel devices would be in terms of the affordance they offer for translational and rotational movement. Another way to operationalize travel would be the amount of control that the user has over viewpoint motion. Based on the task decomposition taxonomy, one can manipulate the degree of affordance for each component of travel by choosing different technique from each of the
sub-tasks for direction selection, velocity/acceleration selection and input conditions. For example, continuous input for steering will provide a greater affordance for movement than ones using target based techniques.

In target based movement in the virtual environment, the user specifies his next viewpoint location. The user is then taken to the new viewpoint through the shortest path between the current and new viewpoint. This is usually achieved using input devices such as wands which can cast a virtual ray to a target object and the virtual camera moves to the target object (Bowman et al., 2005). The user has little control over the movement in terms of the path taken to the new viewpoint, the velocity or acceleration of movement. Continuous input for steering on the other hand requires the user to constantly input the direction as well as the velocity for movement. This usually achieved through input devices such as joysticks which require continuous input through movement of the throttle. This provides the user greater steering control for movement.

Navigational aiding or guidance is seen as information scaffolding for wayfinding. Guidance can be defined as the extent of scaffolding support provided in order to reduce the cognitive effort needed for wayfinding. Many attempts have been made (Edwards & Hand, 1997; Galyean, 1995; Sebok, Nystad, & Helgar, 2004; Smith & Marsh, 2004) to improve wayfinding in virtual environments by developing guidelines or suggesting new tools which aid wayfinding. Chen and Stanney (1999) suggested a navigational tool taxonomy based on the function they perform. Their (p. 679) taxonomy classifies navigation tools (here, they use the term ‘navigation tools’ to mean ‘wayfinding aids’) into five functional categories, which are listed below.

- tools that can display an individual’s current position
- tools that can display an individual’s current orientation
- tools that can log an individual’s movements
- tools that can demonstrate the surrounding environment, and
- guided navigational systems
These tools contribute to improving one or more components of spatial knowledge defined by Thorndyke (1980) – landmark, route, or survey knowledge. Thus wayfinding aids can be operationalized as the degree of guidance provided to perform the navigation task based on the extent of spatial and contextual information provided. Guidance systems in virtual environments take a variety of forms, from ones that orient the user to specific landmarks in the virtual environment (Chittaro & Burigat, 2004) as shown in figure – 5 to electronic versions of “you are here” maps which can provide an overview of the virtual environment as well as continuously track and update the user’s position.

Figure – 5  Guidance system using 3-d arrows to known landmarks
Source: Chittaro & Burigat, (2004, p. 270)

Summary of navigability explication

The explication identified *traversibility* and *guidance* as the two components of navigability. Traversibility, the affordance for movement in the virtual environment was further sub-divided into *environmental constraints* and *steering control*. Environmental constraints refer to the global constraints imposed on movement, which are analogous to constraints in the real world. Examples of environmental constraints in the virtual environment include gravity and collision. Steering controls refers to the choices afforded to the user to maneuver through the virtual environment. The classification of navigability yields us three concepts, which can be manipulated to examine the mechanism by which navigability affects spatial
presence formation. The concepts are environmental constraints, steering control and guidance. The explication can thus be summarized as shown in figure – 6.

![Diagram of navigability explication]

**Figure – 6** Summary of navigability explication

**Spatial presence, explicated.**

The concept of presence, in the broadest meaning of the term, has elicited tremendous interest among many disciplines including media studies, psychology, philosophy and computer graphics among others. Media scholars are interested in studying presence as it is believed to lie at the heart of media enjoyment (Klimmt & Vorderer, 2003). This interest among scholars is mirrored in the technological domain as many communication technologies now aspire to enhance the sense of presence, whether it be for tele-collaboration or tele-operation. An important goal of entertainment media, whether it is television, video games or movies, is to draw the viewer into the world it conjures up and allow them to experience it. This broad sense of ‘being there’ in the mediated environment is commonly referred to as the ‘sense of presence’, or ‘presence’ for short. The shorter version presence, or more specifically “spatial presence,” will be used throughout the rest of the dissertation instead of ‘sense of spatial presence’.

While presence has been studied for over two decades now, defining it is still a challenge. Confusions in presence arise partly due to differences in terminology used by
scholars from different domains to refer to presence (Lee, 2004a). Presence is inherently a multi-dimensional concept (Kalawsky, Bee, & Nee, 1999) and thus capturing its entire breadth of meaning in a single definition is difficult. To add to this, certain dimensions are emphasized over others depending on the research focus. Under their broad definition of presence as the perceptual illusion of non-mediation, Lombard and Ditton (1997) identify six different conceptualizations for presence. IJsselsteijn, Feeman and de Ridder (2002) group these into two broad typologies: physical presence and social presence. Physical presence refers to one’s feeling of being physically located in the mediated space and social presence refers to the sense of being together with one or more remotely located communication partners (Ijsselsteijn et al., 2002). The intersection of these two typologies which result in a sense of being together in a shared mediated space is characterized as co-presence (Ijsselsteijn et al., 2002). This is illustrated in figure – 7 with various media examples.

Since this dissertation is focused on individual navigation in immersive 3-dimensional environments, the review of literature and explication is limited to the physical presence typology. While there are previous explications (Lee, 2004a; Lombard & Ditton, 1997) that attempted at defining presence for a uniform use of the term, the review of literature in this chapter is focused on explicating “spatial presence.” The goal is to define spatial presence
such that the boundaries of its meaning are clearly defined and operationalize it for measurement. Spatial presence has been suggested (Wirth et al., 2007) to be the subtype closest to the original definition of presence by Minsky (1980) and most often used interchangeably with physical presence. The explication builds a foundation to identify the factors influencing spatial presence and explore mechanisms of spatial presence formation as a function of navigability.

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 is not a common communication term and though it can be conceptualized in different ways, for the purpose of this explication, space is treated as a primitive term with its commonly understood meaning.

Preliminary definition

The Oxford English dictionary defines presence as “being present in a place” and its adjective present is defined as “being in the place in question” (Coventry, 1999). 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.
The concept of spatial presence has its roots in the term ‘telepresence’ coined by Minsky (1980). Minsky (1980) used the term to refer to teleporting of actions in a given location to a remote physical location using instrumental devices that feel and work without any noticeable difference. While he stresses the importance of sensory feedback, his definition does not require the feeling of non-mediation to achieve telepresence. For Minsky (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 distinguish it from virtual presence, which is the feeling of being present in a computer-generated environment. Draper, Kaber and Usher (1998) combine the two and use the term to indicate the feeling of being present in either a remote or a computer-generated virtual environment.

The term presence for Steuer (1992) refers to the experience of being present in a physical environment, i.e. natural environment, whereas telepresence refers to being present in an environment through mediated means. This definition of telepresence as subjective experience of being in a different 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 (1992) 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 key to the experience.

This approach is further elaborated by Sas and O'Hare (2003) to include imaginary worlds. Presence is defined 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 physical reality, together with an imperceptible shifting of focus of consciousness to the proximal stimulus located in that other world” (Sas & O'Hare, 2003, p. 524).
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. According to them, telepresence 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” (p.459). Implicit in the “being there” approach to defining presence is Gerrig’s (1993) idea 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. One exception is Lombard and Ditton (1997) whose definitions also includes the idea of object presence (“it is here” as opposed to “being there”) whereby another place or its contents are transported to the user’s immediate world.

While spatial presence definitions have been predominantly approached from an immersion point of view giving more emphasis to sensory factors, alternative ones based on activity and feedback have also been proposed. Environmental presence (Heeter, 1992) is defined along these lines as the extent to which the environment is aware of, and responds to the user action by modifying in some manner various aspects of the environment. For Zahorik and Jenison (1998), presence is synonymous with successfully supported action in the environment. Similar ideas are expressed by Flach and Holden (1998) who emphasize perception-action coupling from a Gibsonian perspective and Mantovani and Riva (1999) who emphasize opportunities for action with considerations to its social and cultural dimensions. Presence definitions discussed above can be broadly grouped into two categories: immersion based ones, focusing on ‘being there’ and activity based ones, focusing on opportunities for action. There have been attempts to arrive at a unified definition of spatial presence, as discussed below.

A recent explication by Lee (2004a, p. 37) defines presence 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 either physical objects, social actors or virtual representations of the self. He identifies three corresponding typologies of presence—physical, social and self. Lee (2004a, p. 44) defines physical presence as “a psychological state in which virtual (para-authentic or artificial) physical objects are experienced as actual objects in either sensory or non-sensory ways”. While Lee 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, his definition is problematic. Lee’s (2004a) definition primarily captures only one dimension of presence, namely reality judgment. It implies a comparison of virtual objects to actual objects, i.e., objects that the user is assumed to have experienced in reality.

Combining the immersion and activity based approaches, Wirth et al. (2007, p. 497) 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, forming a spatial situation model in the mind based on media cues and then of testing whether the primary egocentric reference frame (PERF) is located in the mediated space (Vorderer et al., 2004a). Wirth et al. (2007) definition of spatial presence is an appropriate definition for this study on navigation in virtual world since it captures elegantly the two main dimensions of spatial presence. This definition also takes into account the psychological processes that underlie spatial presence formation. One important extension added to the definition is to qualify the perceived action possibilities as a function of the affordances of the mediated environment. This will help distinguish between psychological and virtual realities, important for making spatial presence distinct from other related concepts such as transportation. For example, perceived action possibilities, as a function of imagination is unconstrained, where as in a virtual environment, it is shaped by the affordances for agent-environment interaction. To
locate this definition within Lombard’s (2006) framework for organizing presence definitions, spatial presence as defined here involves technology – specifically immersive virtual reality technology-- and is a subjective property of an individual experiencing the technology while inaccurately perceiving that technology is not involved and the spatial aspect of the phenomenon is of primary interest.

Operationalization of spatial-presence

Sas and O’Hare (2003) suggest a three step strategy for operationalization of presence, starting with identifying its different conceptual dimensions, finding variables within each of those dimensions that can be measured and finally selecting appropriate measures that capture each variable. The two primary dimensions of spatial presence that are identified from the explication are spatial self-location and possibility for actions. The self-location component of spatial presence is the extent to which the subject feels part of the mediated world forgetting the immediate real environment. The self-location component of presence is seen here as an illusion of position and orientation i.e. presence has to do with a switch from the cues provided by the real world to the cues provided by the virtual world to define one’s position and orientation (Prothero, Parker, Furness III, & Wells, 1995). Here, presence is operationalized as the level of identification with virtual cues over real cues. This method relies mainly on recalling from memory the extent of their self location in the virtual environment (Ijsselsteijn, de Ridder, Freeman, & Avons, 2000) through self-report measures.

Presence is often operationalized as the extent of representational and functional isomorphism between the mediated and its corresponding real world experience. Lee (2004a, p. 38) defines presence in terms of the bivariate relationship between the virtual and actual objects and operationalizes it as the “psychological similarity between virtual and actual objects when people experience – perceive, manipulate, or interact with – virtual objects”. In other words, presence is measured as the extent to which the subjects’ perception and behavior in the mediated environment matches the analogous real world
environment and experience. Thus, someone in a virtual environment which replicates a real world spatial environment should perceive possibilities for action similar to a corresponding real-world scenario.

It is noted that at times, subjective assessments of presence conflict with physiological and physical responses. So another operationalization is based on the logic that, the degree to which a person feels present in a virtual environment, it should evoke perceptual, physiological and behavioral responses similar to those evoked by a corresponding real environment (Ijsselsteijn et al., 2000; Meehan, Insko, Whitton, & Brooks, 2002). Since movement through the virtual environment is central to the research question, vection can be a good indication of the spatial presence and is included as an additional measure. Vection is defined as the subjective sensation of self motion in a stationary observer (Warren, 1995). Stationary observers can experience a compelling sensation of self-motion when the moving visual stimulus covers a wide portion of their field of view. It is expected that when the virtual environment is seen as a stable frame of reference by the participants and their sense of immersion as well as spatial presence is high, their vection is enhanced (Riecke & Schulte-Pelkum, 2006). Vection is thus a very useful measure for spatial presence in the context of navigation.

**Factors affecting presence**

Presence is a multi-dimensional concept and is thus dependent on a large number of interrelated factors (Kalawsky et al., 1999). The number of factors that affect presence are so large that as Lee (2004b) points out, there have been many attempts at a classification system from a simple exogenous (technology-centric)/ endogenous (user-centric) one (Slater & Usoh, 1993) to more sophisticated ones. Kalawsky et al. (1999) classify the parameters determining presence into categories of: demand and supply of attentional resources, understanding of situation, information and technological factors. IJsselsteijn et al. (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 explicitly deal with interactivity in virtual reality and their contribution to presence, are relatively low in number. While interactivity (Schuemie, van der Straaten, Krijn, & van der Mast, 2001) or more specifically navigation (Nash et al., 2000) has been identified as a potential contributor to the experience of spatial presence, the exact process is still not quite understood. While the main focus of this research is on impact of navigability affordances on spatial presence formation, it is important to identify and control for other factors in the categories described above. The research takes the shape of a controlled experiment and all technological variables that are not of interest are held constant across experimental conditions and relevant individual subjective factors are measured to be controlled in the statistical analysis. Review of presence literature suggests that the main user centric variables affecting presence are gender, individual visual-spatial imagery ability, attention allocation and cognitive involvement (Klimmt & Vorderer, 2003; Wirth et al., 2007).

Navigability and spatial presence

Despite the large volume of literature, spatial presence is a poorly understood phenomenon. The exact mechanism of presence formation is still unclear. This is due to the fact that most of the presence studies including empirical ones have focused on the meaning and effects of presence rather than explore why and how presence occurs (Lee, 2004b). Another challenge in presence related studies lies in the lack of clarity in the philosophical foundations underlying these different explanations as revealed in the lively debate in the pages of the Presence journal (Biocca, 2001; Mantovani & Riva, 1999; Sheridan, 1999). Most research on presence approach it from either an immersion point of view (Heeter, 1992; Witmer & Singer, 1998) or an activity based view (Flach & Holden, 1998; Zahorik &
Biocca (1997, 2001) has especially argued for integrating these diverse viewpoints within a more general approach to understanding the nature of mind and agency. Navigability, especially in a 3-dimensional virtual environment offers the opportunity to explore mechanisms of spatial presence formation, drawing from both immersion and activity based approaches. More specifically, the impact of steering control, environmental constraints and guidance – the three components of navigability on spatial presence formation are discussed and specific hypotheses proposed. Spatial presence has been shown to be influenced by both media characteristics and user characteristics (Lombard & Ditton, 1997) and it has been suggested that user characteristics can compensate for technology limitations (Carassa, Morganti, & Tirassa, 2004; Carassa, Morganti, & Tirassa, 2005). Narrative transportation is added as a user-centered variable in this study to investigate its impact on spatial presence formation and to see if it can compensate for the limitations of the three navigability components.

**Steering control and spatial presence**

Sheridan (1992) argues that spatial presence is a function of the users’ ability to control their sensors with respect to the virtual environment. In particular, spatial presence is directly related to the user’s control over positioning his or her sensor mechanisms within the virtual environment. In a navigable 3-d environment, this refers to the ability to modify their own viewpoint in the virtual environment. Thus, better the ability to modify the viewpoint, the greater the spatial presence (Witmer & Singer, 1998). Steering control affords users the ability to move through the virtual environment by modifying their viewpoint within it. Steering control thus enhances the perceptual linkage between the user and the virtual environment by allowing active exploration. This enhanced perceptual linkage can make the users aware that they are actors in a given environment and their willful control of steering can enhance their sense of ‘being there’ as well as ‘acting there’ leading to greater spatial presence (IJsselsteijn, 2002). Spatial presence is also dependent on the range of spatial feedback
(IJsselsteijn, 2002). Previous research (Lombard & Ditton, 1997; Steuer, 1992) have shown that even a simple interactive behavior such as picking up an object, which is limited to the users’ peripersonal space (one’s immediate behavioral space) can enhance spatial presence. Steering control allows for far greater range of spatial feedback extending to the user’s extrapersonal space (i.e., the space beyond one’s immediate behavioral space) and can thus be expected to enhance spatial presence. Enhanced steering control offering better spatial feedback can thus provide strong reinforcement for the ‘medium-as-PERF’ hypothesis. Even in non interactive media like film and television, rapid point-of-view movement has been effectively used as a camera technique to enhance spatial presence. For example, in a car chase sequences or in a racing sequence, the moving camera tries to put the viewer in the scene by giving the impression of seeing the action through the eyes of a character (Lombard & Ditton, 1997).

Biocca (1997, 2001) conceptualizes presence as a subset of the mind-body problem. The phenomenon of presence is closely connected to the phenomenon of distal-attribution or externalization. The perception of objects that we encounter around us is not attributed to sensations they have on our sensory organs but to the objects themselves in the external space beyond the limits of the sense organs (Loomis, 1992). 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. He argues that as long as the subject can successfully represent this linkage internally, it 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. To summarize, the key idea is that the
quality of experience is dependent on the correspondence of efference and afference as well as the quality of the internal representation of this linkage between efference and afference. Greater the steering control, the better the efference-afference linkage leading to better distal attribution. With greater steering control, the user can adjust his navigation behavior in light of the feedback, thus resulting in better coordination between efferent-afferent loops, thus leading to greater distal attribution and feeling of spatial presence. Greater steering control will also increase the breadth of possible actions, resulting in an amplification of the ‘medium-as-PERF’ hypothesis leading to a greater sense of presence. It is not difficult to see that spatial presence is amplified when the constraints are analogous to their real-world counterpart and that there is greater steering control for user input. Thus the following hypotheses can be proposed.

**H**₁: *The greater the steering control, the greater the spatial presence.*

*Environmental constraints and spatial presence*

Environmental constraints in the virtual world imposes limitations on the user’s movement by simulating physical characteristics of a corresponding real environment (e.g. gravity, impermeability of solid objects) and the dynamics of their interaction (e.g. collision). Constraints often make movement in the virtual world analogous to one in the real world. For example, when the movement along the vertical or z-axis is constrained in a virtual environment, the movement in the virtual environment is confined to the ground plane, making it analogous to ‘walking’ in the real world. Thus, constraints make it easier to represent the efference-afference linkage internally through metaphors such as walking. At the same time, they improve the feedback from the environment while moving through it. Thus, based on the distal attribution theory, constraints consistent with our expectations should lead to greater spatial presence. Even when constraints in the virtual environment are not isomorphic with real world ones, distal attribution theory suggests that as long as the user can represent the efference-afference linkage internally or be trained to do so,
constraints need not have a negative effect on spatial presence. An example of this is the ‘fly’ mode of navigation in many virtual environments. While humans cannot fly in real life, the metaphor of flight is easily accessible to them and thus easily represented internally.

On the other hand, if the constraints are analogous to their real world counterpart, they enhance and confirm the ‘medium-as-PERF’ hypothesis. In a similar idea, Lee (2004b) attributes spatial-presence formation to mindless application of folk-physics module to virtual objects on screen. The term ‘folk-physics’ used 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 definition of presence as an experience arising from suspending disbelief and assumes an automatic as opposed to controlled processing of the virtual stimuli (Lee, 2004b). This folk-physics reasoning module is triggered particularly by the media cues such as image size and motion, which are linked to ones’ survival instinct. Numerous research results supporting mindless application of these folk-physics and a similar folk-psychology are reported by Reeves and Nass (1996). We constantly judge the response to our actions in the virtual environment whether initiated by us or by the environment itself as a set of reality tests. If the responses or feedback from the virtual environment are consistent with our mental representations, we are more likely to be convinced of its authenticity and accept it at face value, thus increasing the chances of feeling present in it (IJsselsteijn, 2002). Based on the above discussion, we can propose the following hypothesis.

H2: The greater the number of constraints in the virtual world that correspond to ones in the real world, the greater the spatial presence.

The discussion so far described how steering control and environmental constraints can independently influence spatial presence formation. It can be assumed that when navigability is high, arising from greater steering control and more number of environmental constraints analogous to real world, their combined effect on spatial presence is amplified.
Thus the following hypothesis can be proposed.

\[ H_{12}: \text{There will be a significant interactive effect between environmental constraints and steering control as illustrated below.} \]

![Interactive effect of steering control and constraints on spatial presence](image)

**Figure – 8** Interactive effect of steering control and constraints on spatial presence

When there are fewer environmental constraints analogous to real world, there will not be much difference in spatial presence between high and low steering control. But, when the environmental constraints are greater, the impact of high steering control on spatial presence will be much more pronounced compared to low steering control.

*Guidance and spatial presence*

There has hardly been much research which examine the direct impact of guidance or wayfinding aids on spatial presence in the context of virtual environments. Most of the research on guidance in virtual environments is focused on the use of such environments to train spatial abilities for complex tasks. While guidance systems can improve the navigation and task performance in virtual environments, their addition often makes the environment less realistic and can degrade spatial presence (Arnold & Farrell, 2003).

Wirth et al. (2007) argue that while a stronger SSM requires less support for the ‘medium-as-PERF’ hypothesis to be confirmed, it still needs to be confirmed for the formation of spatial presence. This confirmation depends on both media as well as user factors. On
one hand, better guidance can lead to better SSM, improving the chances of forming spatial presence. On the other hand, it can also decrease the cognitive involvement needed to navigate on the part of the user leading to lower spatial presence. Since guidance can affect spatial presence in either direction, and given the lack of prior research to propose a directional hypothesis, the following research question is proposed.

**RQ1:** What is the relationship between guidance and spatial presence?

Spatial presence is a multi-dimensional construct influenced by both media-centric and user-centric variables. Prior research have identified attention allocation, cognitive involvement, suspension of disbelief, gender and visuo-spatial abilities among others as primary user-centric variables affecting spatial presence. However, in this study narrative transportation is included as a user-centric variable while controlling for other user-centric variables just listed for a couple of reasons. First, narratives are critical for entertainment media, whether it be a novel, cinema or interactive video game. It will be interesting to locate a subject in a role within the narrative and examine the impact on spatial presence. Second, user characteristics in general (Lombard & Ditton, 1997) and narratives in particular (Carassa et al., 2004; Carassa et al., 2005) can suppress or enhance the impact of media-centric variables on presence depending on the nature of the narrative.

**Narrative transportation and spatial presence**

A significant portion of the transportation research is within the context of stories (irrespective of the medium in which they are told) or more precisely in the world of narratives. All of us are familiar with the experience of being ‘lost’ in a good novel or a movie and in simple terms, transportation is the “experience of being temporarily immersed in a story” (Green & Brock, 2002). Transportation is the process by which readers who are totally immersed in the world conjured up by the narrative fail to keep track of both time as well as events around them (Green, 2004). Transportation is conceptualized as a distinct mental
process and defined as combining “attention, imagery, and feelings” resulting from the focus on story events (Green, 2004; Green & Brock, 2002; Green, Brock, & Kaufman, 2004). Transportation process here is conceptualized as being independent of the medium. Arguably, certain media can be better than others. The metaphor of transportation into narrative worlds is analogous to physical transportation in the real world. Here, the role of the reader and the construction of an alternate reality is primarily determined by the text, though the user may import his own experience into the textual world (Ryan, 2001). For Green and her colleagues, the world of origin is inaccessible due to attention being focused on the story events. Ryan (2001) adds that this happens also due to the over-ruling of the real-world principles by the idiosyncratic laws of the narrative world. Another critical aspect of the metaphor of transportation is that it captures how the textual world is constructed and comes alive in the mind and not how this imaginative world relates or compares to a corresponding real world. This difference is critical to compare and distinguish transportation from spatial presence. In the case of transportation, the interaction exists mainly in the mind of the observer and is intangible. For spatial presence, the locus of interaction is in a ‘virtual space’ - a space that appears to have an extension in space and tangible properties, but whose existence rests mainly on the user’s interaction with the technology.

In the case of narrative transportation, the emphasis is more on locating the reader or viewer within the narrative structure. On the other hand, the participant should have affordances for action in addition to locating oneself in the mediated space for spatial presence to occur. Greater narrative transportation can thus create stronger expectation hypothesis that the medium is the primary ego reference frame, which requires very little supportive information to confirm it. Narrative transportation is particularly relevant for spatial presence in contexts like video games where the participant is also the key protagonist. A video game player’s spatial presence as well as his enjoyment may potentially be strongly tied to the narrative transportation.
An integration of the narrative transportation idea in spatial presence formation can be seen in the works of Carassa and her colleagues (Carassa et al., 2004; Carassa et al., 2005) who attempt to explain presence formation from the perspective of situated cognition. They differ with 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.

According to Carassa, Morganti and Tirassa (2005, p. 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”. The emphasis here is on the quality of the interaction afforded by the medium rather than its representational isomorphism with a corresponding real world environment. Presence here is approached from a subjective perspective and is rooted in the narrative that the agent finds himself/herself in. Greater narrative transportation and awareness of the navigational situation with respect to its purpose, goals and expected actions can lead to stronger sense of spatial presence compared to a context where this information is absent.

**H3**: The greater the narrative transportation, the greater the spatial presence

The navigability explication and hypotheses discussed above can be summarized as in figure - 9.

The discussion so far was centered on the direct effect of navigability and narrative transportation on spatial presence. Wirth et al. (2007) contend that spatial presence formation is a two-step process with the formation of spatial situation model (SSM) from the media cues as the first step. Spatial presence arises when the medium as PERF hypothesis is repeatedly confirmed from the SSM. The essence of the Wirth et al. (2007) argument is
that SSM mediates the spatial presence formation. For SSM to mediate the impact of navigability on spatial presence, we need to show that there is a direct relationship between SSM and spatial presence as well as between navigability and SSM.

**Spatial situation models (SSM)**

Users mental model of the situation depicted in the media is referred to as the situation model. These situation models are multi-dimensional and include spatial, temporal and causal information among others (Rinck, 2001). One specific type of information depicted in this situation model pertains to spatial information and hence they are referred to as spatial situation models (SSM) (Rinck, 2001). The construction of the SSM is facilitated by spatial cues presented by the medium as well as personal spatial memories and cognition (Wirth et al., 2007). Media users process available spatial cues and try to organize them into a comprehensive structure. Any gaps in the situation model are filled using personal spatial knowledge from prior experiences and continuously updated with more accurate information from the perceived spatial data (Wirth et al., 2007).
**Construction of spatial situation models (SSM) from navigability and narratives**

In large-scale environments (both virtual and real) where the entire space is not seen from a single vantage point, humans acquire their spatial models from a number of sources. Perhaps the two most important sources are direct navigation experience obtained by moving through the environment and from external representations in the form of maps, pictures, or route descriptions.

**Steering control and SSM formation**

While moving through the virtual environment, one acquires spatial knowledge from the spatial cues provided by the media. The spatial knowledge thus acquired is organized and structured into spatial situation models and consistently checked for their accuracy and modified based on further exploration (Avraamides, 2003). Wirth et al. (2007) suggest that spatial cues are the building blocks of SSM. Steering controls help the subject to extract spatial cues directly from the virtual environment by moving through it. These include both static monocular cues such as occlusion as well as dynamic clues such as motion parallax. Steering control by better facilitating movement within the virtual environment can improve spatial encoding through the path integration\(^1\). Path integration usually takes odometry data from optic flow and other modalities such as proprioception (Mallot, Gillner, van Veen, & Bulthoff, 1998). Even though proprioception may be lacking in certain virtual reality environments, Wartenberg, May and Peruch (1998) have shown that spatial structure of the environment is contained in the continually changing retinal information. Riecke, Cunningham and Bulthoff (2006) also show that humans can extract distances and angles from pure optic flow information. Steering control provides users the opportunity to examine the virtual environment from multiple points of view resulting in better encoding of spatial information.

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\(^1\) In mathematical terms, path integration is the integration of one’s self-movement to form a position vector by combining the velocity vector with time (Wilson & Keil, 2001).
information. Spatial situation models formed as a function of steering control are strong since they have greater internal logical consistency regarding the spatial relationships (for example, how different rooms are arranged). Rinck (2001) suggests that SSMs include both Euclidean distance (measured in feet and inches, i.e. at the ratio level) as well as categorical distance (e.g. one room separates lobby from the kitchen). Steering control provides opportunity to represent both types of distances to form better SSM by facilitating movement through virtual environment. Based on the above discussion, the following hypothesis can be proposed.

H4: The greater the steering control, the better the spatial situation model (SSM).

Guidance and SSM formation

Guidance is essentially the support provided for finding one’s way through the virtual environment. Types of spatial information support in the context of navigation can be broadly classified into three - landmark, route and survey knowledge in the order of increasing information richness (Cubukcu & Nasar, 2005; Thorndyke, 1980). Research in urban environments have shown that even in the absence of guidance systems such as a map or a global positioning system (GPS), people form an ‘image of the city’ from elements of urban environments such as landmarks, nodes, routes, districts and edges (Lynch, 1960). This ‘image of the city’ is nothing more than an elaborate spatial situation model. Rinck (2001) provides evidence of research where provision of route knowledge led to increased or better SSM. Recognition based guidance systems (Chittaro & Burigat, 2004) provide users with direct knowledge of spatial organization, and visual information which help them determine their current position in the virtual environment. A common implementation of guidance system in virtual environments takes the form of an electronic map which provides survey knowledge as well as indicate user position and orientation in real-time. Any guidance system provided in a virtual environment, irrespective of the metaphor used (3-d arrows in space, electronic maps etc.), serves to enhance the spatial knowledge structure with respect to landmark, route or survey knowledge leading to better spatial situation model.
**H5:** The greater the guidance, the better the spatial situation model (SSM).

*Narrative transportation and formation of SSM*

Implied in the transportation theory by Gerrig (1993) and Green and colleagues (Green, 2002, 2004; Green & Brock, 2002; Green et al., 2004) is the idea of formation of an alternate reality. While their discussion of narrative transportation does not explicitly state the formation of a spatial situation model, they allude to formation of situation models which make readers forget their immediate surroundings and get lost in the narrative. There is sufficient support in the literature (Rinck, 2001; Zwaan, Radvansky, Hilliard, & Curiel, 1998) for formation of spatial situation models from narrative text. Rinck (2001) suggest that one component in the comprehension of a text is the formation of spatial situation model. Spatial relationships embedded in the spatial situation model include spatial locations and objects, their spatial relationships and distances, current location as well as the movement path of the protagonist through different locations (Rinck, 2001). Similar to updating of SSMs through visual-spatial cues suggested by Wirth et al. (2007), Dutke and Rinck (2006) have shown that SSMs are constantly updated and influenced by the visuo-spatial abilities of the reader in text based narratives. While majority of the literature on SSM formation from narratives is focused on text or print modality, it can be safely extended to the visual modality which inherently offer more spatial cues.

**H6:** The greater the narrative transportation, the better the SSM

The hypotheses pertaining to SSM formation can be summarized in the following figure.
Wirth et al. (2007) 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 being 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 (Vorderer et al., 2003; Wirth et al., 2007).

**From spatial situation model (SSM) to spatial presence**

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. In order to orient themselves within a space and navigate through it, individuals maintain an egocentric reference frame, i.e. mental model of the world based on a first person perspective. A mediated space provides the subject with another choice to locate the 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.
A strong SSM does not automatically result in the confirmation of ‘medium-as-PERF’ hypothesis. However, based on the theory of perceptual hypothesis (Gregory, 1980), a stronger expectation hypothesis requires less supporting information for confirmation. According to Wirth et al. (2007), a rich and consistent SSM gives rise to a strong ‘medium-as-PERF’ hypothesis which increases the probability of its acceptance and spatial presence formation (as long as there are no inconsistencies which cause breaks in presence). Thus the following hypothesis is proposed:

\[ H_7: \text{The better the spatial situation model, the greater the spatial presence.} \]

The hypotheses and research questions discussed above relating to spatial presence can be summarized in the following figure.

![Figure 11: Overall Mapping of Hypotheses](image-url)
Spatial presence and enjoyment

Wirth et al. (2007) as well as Klimmt and Vorderer (2003) have suggested that spatial presence can potentially increase the enjoyment of media events, especially sports events. In such events having a strong spatial component, an audience member is motivated to locate himself within the arena to be part of the action. Meehan et al. (2002) have shown that subjects react affectively to stressful virtual environments. While Vorderer and his colleagues (Klimmt & Vorderer, 2003; Vorderer et al., 2003) have speculated on the potential relationships between presence and media effects, research is lacking to postulate any directional hypothesis or to speculate on the mechanisms of the relationship if any. The following research question is proposed to explore if indeed a relationship exists between spatial presence and enjoyment.

RQ$_2$: What is the relationship between spatial presence and enjoyment in the case of navigable environments?
A controlled experiment was conducted to investigate the research questions and hypotheses described earlier. This chapter provides details of the experiment design and the settings. Independent variables are defined for clarity of meaning. While theoretical definitions clarify meaning, observable criteria must be laid down for experimental manipulation of these independent variables. Operationalizations of these variables based on their respective definitions and their implementation within the virtual reality environment are discussed next. The latter half of this chapter provides a vivid description of the virtual environment created for experimental design, details of the procedure for the experiment and the control and dependent measures employed in the study.

Experiment design

Navigability, the affordance of navigation was broken down into traversibility and guidance through explication. Traversibility sub-divided into two components: steering control and environmental constraints. The first set of hypotheses regarding the impact of navigability were centered on steering control, environmental constraints and guidance. The last pair of hypotheses concerned the impact of narrative transportation. Thus the research had four independent variables as listed below, each having two levels

- Environmental constraints (high / low)
- Steering control (high / low)
- Guidance (high / low)
- Narrative transportation (high / low)

The research was designed as a 2 (high / low – environmental constraint) x 2 (high / low - steering control) x 2 (high / low - guidance) x 2 (high / low – narrative transportation) between
subjects, full factorial experiment. Gender is often seen as influencing presence and is therefore included as a control measure. Since subjects were recruited from different majors, it was possible that due to the difference in training, the academic major could have a strong influence on spatial presence. It was added as another control measure. The operationalization and implementation of the independent variables are discussed later in this chapter.

**Experiment setting**

The research was carried out in the Immersive Environments Lab at Penn State University. The lab offers a panoramic three 6’ by 8’ screen, rear projected, passive, stereoscopic virtual reality display supported by graphics workstations running Windows operating system. See figure - 12 for a view of the Immersive Environments Lab display. The rear projection display helps to avoid any subject interference with the projected images. There are two projectors for each screen, with each projecting a slightly different image for left and right eye through linear polarized filters. The subjects experience a 3-dimensional stereoscopic image on screen when viewed through a pair of passive stereo glasses with polarization for each eye corresponding to its respective projector filter. A standard wireless optical mouse and Logitech Freedom 2.4™ wireless joystick were used for graphical input, with the joystick used exclusively for navigating the virtual environment. The experimental subject was seated on a chair aligned with the center of the middle screen and a few feet away from the screen to be in the ‘sweet spot’ for viewing the stereoscopic display. The interior of the lab is painted black and the lights were dimmed to avoid distractions.
Figure – 12. Stimulus presentation in the IEL.
Office Environment presented on the three-screen stereoscopic display in the IEL. The subject was seated a few feet away from the screen and navigated through the office environment using the joystick.

**Stimulus details**

The stimulus was staged as a video game under development based on the theme of the popular television series – CSI: Crime Scene Investigation™ (CSI™). The subjects were instructed that they will navigate a CSI™-based game in the virtual reality environment. The specifics of the game plot as well as the game environment, user interface and the navigation controls were developed from scratch for this research and did not use any commercially available CSI™ video game content. Unlike reality, virtual environments cannot extend in all directions endlessly and need a well-defined boundary to avoid having a ‘falling off from the edge of the world’ experience. In other words, the players must be locked in a closed space to avoid exposure to the limits of the virtual environment. An interior office space was thus chosen as the context for the game environment. An office space located in a high-rise building was developed as the environment for this study. The space was sufficiently large for the user to spend about 10 minutes exploring it at a relaxed pace. Special attention was paid to ensure that the furniture and other elements were
proportionate, and when displayed on the large screens of the IEL, they would be as close to the human scale as possible. The office interior consisted of distinct spaces such as reception, waiting lounge, manager's cubicle, conference spaces, and dining areas. See figure – 13 below and appendix - D for a better understanding of the stimulus. The virtual reality model simulated the material characteristics as close to reality as possible without slowing down the navigational performance.

Figure – 13. Image of the virtual reality office environment interior

The virtual office environment was created using 3D Studio Max, a commercial 3-d modeling software and exported to virtual reality modeling language (VRML) file format. VRML files can be viewed and navigated using VRML viewer applications such as BS Contact™. Multiple VRML instantiations of the basic office environment were created to correspond to the experimental condition as determined by the manipulations of the independent variables. The final office stimuli for all experimental conditions were presented full screen with menus and other interface elements hidden to make the experience as seamless as possible. These instantiations differed in their extent of steering control, environmental constraints and navigation aid. Theoretical and operational definitions of each independent variable and their implementation with respect to the stimulus and navigational task are described below.
Independent variables, their operationalization and implementation

Explication of navigability in the previous chapter yielded concepts of steering control, environmental constraints and guidance. These three concepts and narrative transportation were included as the independent variables in the experiment, with each having two levels. Operational definitions of these independent variables and their implementations in the experimental stimulus are discussed below.

Steering-control

Steering-control in this study was defined as the extent of user maneuverability to follow a desired course within the virtual environment. Steering control arises from the user's ability to specify movement characteristics for any given segment in the virtual environment with respect to the direction of rotational and translational motion as well as vary the above characteristics from segment to segment. Operationally this translates into presence of interface features to specify the direction of translational motion as well as the axis of rotational motion at any given point while moving through the virtual world. Given the ego-centric nature of this investigation, navigation in both low and high steering control were from a first person point of view.

In the high steering control condition, the user could execute translational motion along both forward-backward direction and sideways as well as pan (rotational motion along the z-axis similar to ones ability to turn around in the given world) and tilt within a certain limit imitating an upright person’s ability to look up or down. Please see figure – 14 and figure – 15 for a better understanding of the maneuverability aspects described here and how they were implemented in the joystick. In the low steering control, the only movement choices the subject had were the forward-backward translational motion and pan (rotational motion along the z-axis). These movement choices were implemented by programming the joystick to limit specific translational and rotational motion based on the steering condition.
While training the subjects to use the joystick, care was taken to ensure that they were not primed about the limitations in the low steering control condition. During the training session to use the joystick, the tone of the verbal script was held as consistent as possible across both conditions to avoid any negative attitude in the low-steering condition. The only
additional information given in the high steering condition pertained to sideways motion and
the up-down tilt. Subjects in the low steering control were told:

The use of joystick is very simple and straightforward. To move forward, move
the stick forward and to move backward, bring it backwards. To turn, move the
joystick to the right or left. Other types of actions using the joystick such as
twisting or use of buttons are disabled will have no effect on your movement.
Since the distances to be covered are usually small, please use delicate
movements of the joystick. This is important for turning tight corners and to
ensure that you do not overshoot your desired target. Settle for a pace that is
comfortable for you.

Subjects in the high steering condition were told:

The use of joystick is very simple and straightforward. To move forward, move
the stick forward and to move backward, bring it backwards. To turn, move the
joystick to the right or left. Some times it is useful to slide to one side or another
rather than turning, such as when you have to make slight adjustment to the
path. To slide, press the thumb button while moving the joystick to the side that
you want to slide to. If you desire to look up or down, you need to use the trigger.
To look down, pull the trigger and move the joystick forward. To look up, pull the
trigger and move the joystick backward. Other types of actions using the joystick
such as twisting or use of buttons other than the trigger and the thumb are
disabled will have no effect on your movement. Since the distances to be
covered are usually small, please use delicate movements of the joystick. This is
important for turning tight corners and to ensure that you do not overshoot your
desired target. Settle for a pace that is comfortable for you.

**Environmental constraints**

Environmental constraints in this study were defined as restrictions imposed by the
virtual environment (independent of the user's abilities) on movement through the virtual
space and consistent throughout the space. Additionally these restrictions imposed in the
virtual environment were analogous to limitations imposed by a similar physical environment
(e.g. gravity, collision etc). The latter specification is important since one of the primary
intentions in including this variable was to test the folk-physics explanation of spatial
presence. Environmental constraints were operationalized as restrictions for rotational and translational movement imposed across the virtual environment and limitations on the ability to pass through solid objects. The low constraint condition was implemented by restricting movement to the horizontal plane mirroring the gravitational pull in the real world. The high constraint condition was implemented activating collision detection which prevents passing through solid objects in addition to restricting movement to the horizontal plane analogous to walking. Again, like the steering control instructions during the joystick training, the tone of the verbal instructions were kept similar to avoid any negative attitude. Specifically, subjects in the high constraint condition were told:

*The advantage of this environment is such that it mimics real world settings. For example, you cannot pass through solid objects. When you come to a solid object you cannot pass through it and will have to go around it.*

The subjects in the low constraint condition were told:

*The advantage of this environment is such that it can overcome real world limitations. For example, here you can pass through solid objects. When you come to a solid object you can pass through it and will have to decide if you want to pass through it or go around it.*

**Guidance**

Guidance was theoretically defined as provision of information to reduce the cognitive effort required for wayfinding. Guidance is characterized by presence of information for wayfinding, which will specify the user's location with respect to known features and spaces. Earlier in the literature review, we discussed how landmark, route and survey knowledge inform our way finding. In this study, guidance was operationalized as the provision of real-time information regarding the user's current position and orientation in office environment. A 'head's-up display' resembling a tablet PC was implemented in the virtual office environment. This tablet PC dashboard was presented to the subjects as standard equipment issued to CSI\textsuperscript{TM} agents and was always displayed at the same location.
on the screen as subjects moved through the office space. The VRML file for the office environment was implemented with a grid of proximity sensor nodes that would detect the user’s current location in the office and transmit that information to the tablet PC dashboard. Similarly, the proximity sensor nodes near the location of the clues also transmitted that information to the tablet PC dashboard to alert the users about their proximity to a clue.

In the high-guidance condition, the tablet PC dashboard presented the subject with a layout plan of the office space, indicating their current location clearly with a bright red circle. The layout was labeled with respect to the function of the spaces and also presented clearly the furniture layout of each space. See image – 16 for implementation of tablet PC dashboard for the high guidance condition.

![Image of dashboard in the high guidance condition.](image)

In the low guidance condition, the ‘head’s-up display, the layout plan, was absent, and the subject’s position in the office space was not presented. Instead, it merely had 4 large icons with only the clue alert feature implemented. The subject had to rely entirely on the cues
provided by the environment for guidance. Since the office environment used for the stimulus had clearly distinguishable spaces and interior landmarks, it provided the users inherent spatial layout cues. See figure – 17 for implementation of tablet PC dashboard for the low guidance condition.

![Image of dashboard in the low guidance condition.](image

The map and real-time location update are absent in the low guidance condition

**Narrative transportation**

It was hypothesized that the greater the narrative transportation (i.e. the extent to which a given subject locates himself within a narrative and uses that narrative to provide meaning to actions in the virtual world), the greater the sense of spatial presence. Narrative transportation is theoretically defined in this study as the extent to which the subject’s role is located in an existing meaningful narrative that the subject can bring to bear on his or her actions in the virtual environment. Drawing on prior operationalization of narrative transportation in psychology (Green & Brock, 2000; Green, Brock, & Kaufman, 2004) and marketing research (Escalas, 2004, 2007), both high and low narrative transportation conditions were provided with almost identical narratives with small variations in text and
instructions to induce either low or relatively high levels of narrative transportation. In the series of studies undertaken by Green and her colleagues, the extent of transportation was successfully manipulated through the instructions for reading the narrative. In previous studies (Green & Brock, 2000; Green, Brock, & Kaufman, 2004), instructions for the high narrative transportation condition encouraged the reader to get immersed in the text whereas in the low narrative transportation condition, subjects were forced into an evaluative state of mind by making them focus on a surface aspect of the text – its comprehensibility for a fourth-grader and identifying difficult areas in the text. Their manipulations using reading instructions were adopted for this study with modifications to suit the modality. The study was presented to the subjects as evaluating a CSI™ based game developed for the virtual reality environment. The study context of CSI™ game was chosen to create an opportunity to incorporate a narrative that is meaningful for the navigation task. The context of a crime scene also provides the subject with motivation to explore the entire environment in detail in search of ‘clues’.

The narrative transportation manipulations were carried out at three points in the study. First, in the overall instructions regarding the role of the subject in the study. Those in the high narrative condition were told that their part in the research was to test out the game environment by role-playing a CSI™ agent and those in the low narrative condition were asked to evaluate the aesthetic quality of the game environment. Those in the high narrative condition were told:

*Your part in the research is to role-play a CSI™ agent looking for clues in a crime scene. So try to keep this in the back of your mind for every task involved in the study. Use your imagination. Think about the setting, about how you might feel in the situation as a real-world crime scene investigator. Immerse yourself the action of the story. Pay attention to all incidents described in the plot. These aspects are critical to the younger audience towards whom the game is targeted.*

Those in the low narrative condition were told:
Your part in the research is to evaluate the overall visual quality of the CSI™ game’s opening screens and the game environment. Use your evaluative skills. Think about the overall quality of the presentation. Pay more attention to the overall composition, font quality and size, quality of visuals etc in the opening screens. These aspects are critical to the younger audience towards whom the game is targeted.

After training the subjects to use the joystick, the narrative transportation manipulations were reinforced through instructions before presenting the subjects with the opening screens of the game environment. The context of the screen shots was that the head of the CSI™ unit briefing the gamer, who plays a new recruit in the CSI™ unit. Subjects in the high narrative transportation were told:

Now that you are comfortable with using the joystick, I will present you with the opening screens being developed for the game. After this you will be presented with the game environment. Imagine that you are a CSI™ agent in Grissom’s unit and you are about to be briefed by Grissom on a case. While viewing Grissom’s briefing in the presentation, use your imagination. Think about the setting, about how you might feel in the situation as a real-world crime scene investigator. Immerse yourself in the action of the story. Pay attention to all incidents described by Grissom. It is important to pay close attention to instructions following the briefing, which are concerned with certain display tools available for your use in the game environment. Once you have completed going through the opening screens of the game, you will be automatically taken to the game environment where you will continue to assume the role of a CSI™ agent and try to solve the crime. When you are at the crime scene, examine each nook and corner of the office thoroughly for any clues. When you find a clue, make a mental note of it and keep looking for further clues. You will be given 10 minutes to explore the crime scene and try to solve the case after which you can complete the second questionnaire.

Subjects in the low narrative transportation were told:

Now that you are comfortable with using the joystick, I will present you with the opening screens being developed for the game. After this you will be presented with the game environment. The new CSI™ game is targeted at much younger
audience and as such the needs to be evaluated for its visual quality of the opening screens as well as for the eventual game environment. In the given handout there are screenshots from the opening screens. Against each screen is a set of evaluative criteria. Please mark scores out of 10 for each item for a given screenshot. Once you have completed the evaluation, the instructions displayed on screen are concerned with certain display tools available for use in the game environment. It is important to pay close attention to these instructions. Once you have completed going through the opening screens of the game, you will be automatically taken to the game environment. The gamers are required to find clues to solve the crime described in the opening screens of the game. It is important to evaluate the overall quality of the CSI™ game environment as you explore the game are looking for clues. Even factors like the number of interior doors and if they are wide enough, number of windows and if they offer views of the exterior, if the interior color schemes match and if the rooms are adequately and appropriately furnished are all important. So, while you are searching for clues, keep a rough mental note of the number of interior doors and number of narrow ones, number of windows and the ones which don’t provide a good view, overall quality of the color scheme and the furniture arrangement. When you find a clue, make a mental note of it and keep looking for further clues. You will be given 10 minutes to explore the game environment for clues after which you can complete the second questionnaire.

Also, following the work of Escalas (2004, 2007), narrative self-referencing which encouraged the subject to mentally simulate the narrative described in the text, was used in opening screens of the game in the high narrative condition while self referencing was avoided in the low narrative condition. In the low narrative condition, the text in the opening screens were written in passive voice. For example, in the opening screen of the game, in the high narrative transportation, against the investigator’s name field², the subject’s actual name appeared where as in the low narrative transportation condition, a generic id “LVPD 0039” appeared. This screen was followed by an introduction to the game environment. In

² It is common in video games to enter the name of the player and that is usually one of the first steps in game. This is done to personalize the rest of the instructions and game play.
the high narrative transportation condition, the introduction was presented as done by “Gil Grissom”, the chief of the Las Vegas Police Crime Scene Investigation team. The player is considered as a new recruit and Grissom welcomes him/her and briefs about the investigation task. On the screen next to Gil Grissom’s picture the following text appeared “Hi, I am Gil Grissom, your supervisor. Thanks for coming in at such short notice to take up your first case. But, that is the life of CSI. We do not have a lot of time before you have to be at the crime scene, so we will keep this briefing short. But first of all, Welcome to the Vegas Police Dept. and CSI!” In the low narrative condition the introduction was in passive voice and on the screen next to Gil Grissom’s picture the following text appeared “Gil Grissom, the supervisor at LVPD CSI. CSIs have to be available on short notice to take up any case. Such is the life for a CSI. CSIs generally do not have a lot of time before they have to be at the crime scene & so the briefings are short. Next, an overview of the Las Vegas Police Dept. and CSI!” Please see Appendix – C for the details of the opening screen shots in both high and low narrative conditions.

Variables and their measures

Measures for Spatial Presence

Items from the MEC-SPQ (Vorderer et al., 2004a) was used to capture the spatial self-location and possibilities for actions dimensions of spatial presence. Spatial self-location was measured using three items on a 10-point Likert-type scale from 0 (strongly disagree) to 9 (strongly agree). The items captured the extent to which the subjects located their ego-reference frame in the virtual office environment (e.g. “I felt as though I was physically present in the office environment). Possibilities for action was also measured using three items on a 10-point Likert-type scale from 0 (strongly disagree) to 9 (strongly agree). The items measured the extent to which the participant felt he or she could freely act in the office environment (e.g. “It seemed to me that I could do whatever I wanted in the office environment”). Five items from Banos et al. (2000) was used to capture reality judgment as
an additional presence measure since the virtual environment created for the experiment was analogous to a real one. Items captured the extent to which the experience in the virtual office environment congruent to experiences in the real world [e.g. “To what extent did your interactions within the office environment seem natural to you, like in real world” measured on a 10-scale from 0 (not at all natural) to 9 (highly natural)]. Four items adapted from Riecke & Schulte-Pelkum (2006) were used to capture vection [e.g. “I felt a compelling sensation of self-motion within the office environment”]. The vection items were measured on a 10-point Likert-type scale from 0 (strongly disagree) to 9 (strongly agree). See appendix- A for listing of all items measuring the different spatial presence dimensions.

Measures for spatial situation model

The participants’ spatial situation model was measured in two ways. First was through the items in the self-report measures of spatial situation model developed by Vorderer et al (2004) as part of the MEC-SPQ. Five items captured the spatial situation model on a 10-point Likert-type scale from 0 (strongly disagree) to 9 (strongly agree) [e.g. “I was able to imagine the arrangement of the rooms in the office environment very well.”]. As a secondary measure, the subjects also completed a puzzle task, which captured their spatial situation model. The task required them to arrange images of rooms as they were laid out in the office environment and match objects from a given list to the rooms where those objects were located. More details regarding the puzzle task used to capture the spatial situation model are given in the procedures section. The solutions to the puzzle task were scored for their accuracy to capture the spatial situation model of the participant.

Measures for control variables

Items were adapted from the MEC-SPQ (Vorderer et al., 2004) to a 10-point Likert-type scale from 0 (strongly disagree) to 9 (strongly agree) and used to measure attention allocation, cognitive involvement and suspension of disbelief, to be used as control
measures. Three items were used to measure attention allocation (e.g. “I devoted all of my whole attention to the office environment.”). Cognitive involvement was measured using four items (e.g. “Much of my thinking had to do with the office environment.”). Suspension of disbelief was measured using three items (e.g. “I did not concentrate on whether there were any inconsistencies in the office environment.”)

Another important control is the individual’s visual imagery preferences and experiences. The Object-Spatial Imagery Questionnaire (OSIQ) (Blajenkova, Kozhevnikov, & Motes, 2006) was adapted to a 10 point Likert type scale and used to control for individual visual imagery preferences. The OSIQ consisted of a fifteen item object imagery scale to assess preferences for representing and processing vivid images of individual objects and spaces (e.g. “my images are vivid and photographic”, “I can close my eyes and easily picture a scene that I have experienced”) as well as a fifteen item spatial imagery scale that measures preference for schematic images and relationship among objects (e.g. “my images are more like schematic representations of things and events rather than detailed pictures”). Since the study dealt with navigational guidance, it was important to account for individual differences in environmental spatial ability. The Santa Barbara Sense of Direction (SBSOD) scale (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002) was adapted to a 10 point Likert type scale and used to measure environmental spatial ability. The SBSOD scale consisted of 15 items (e.g. “I am very good at giving directions”, “I am very good at reading maps”). Please see Appendix – A for items in each of these scales.

Demographic measures

Demographic variables of gender, academic major and year standing can affect spatial ability, a factor that can impact spatial presence formation and thus used as control measures. Computer and gaming skills can also be potential confounds and therefore experience with 3d modeling software / CAD, experience with video games as well as
experience with use of joystick and other navigational input devices were also measured. Please see Appendix – A for a detailed list of demographic items.

*Manipulation checks*

The post navigation task questionnaire also contained items aimed at detecting if the manipulations of the independent variables were indeed effective. Manipulation check items for steering control captured the ease and freedom for translational and rotational motion (e.g. “How restricted was your sideways movement using the joystick?”, “How widely could you turn around using the joystick?”). Items to detect the effectiveness of the environmental constraints manipulation captured the participants’ impression about their ability to move through solid objects (e.g. “To what extent did you feel like you could move through solid objects?”) and their overall ease of movement through the office environment (e.g. “To what extent did you feel that walls and other solid objects in the office space obstructed your motion?”). Items for guidance manipulation check captured the extent to which the tablet PC dashboard was useful in locating the position in the office environment and the office layout, amount of attention paid to the dashboard while moving through the office space and its usefulness for detecting clues. Selected items from the narrative transportation scale (Green & Brock, 2002; Green, Brock, & Kaufman, 2004) were used as manipulation check items (e.g. “I could easily relate to the role of a crime scene investigator.”, “While reading the briefing of the case in the screen shots, I found my mind wandering”) for measuring the effectiveness of the narrative transportation manipulation. All manipulation check items are listed in Appendix – A.

*Participants*

Participants (N = 240) were recruited from undergraduate communication courses in exchange for extra course credit. The age of the participants ranged from 18 to 26 years with the average age being 20.39 years (S.D. = 1.07). Majority of the participants were females
(67.80%). Most of the participants were from the college of communications (87.05%), and a majority among them in their sophomore (37.71%), junior (35.59%) or senior year (23.73%). The participants on average used computers for about 14.05 hours per week for course related purposes (S.D. = 17.19) and about 16.48 hours per week for personal or leisure activities. The participants reported spending on average 2.21 hours per week on playing video games, and a majority of them (69.92%) reported using joysticks for videogames or computer applications on previous occasions. While a majority of the participants (63.98%) reported having watched the CSI television series on some occasion, an overwhelming majority of the participants (94.89%) had never played a video game based on the Crime Scene Investigation television series.

**Procedure**

The experiment was administered to participants individually. Participants were randomly assigned to one of the 16 experimental conditions. The table – 1, given below, lists the number of subjects in each experimental condition and the gender distribution in each condition. The presentation of the opening screens of the CSI™ game environment developed for the study, the VRML model of the office environment based on the experimental condition and the training environment for the joystick were loaded onto the large screen display of the Immersive Environments Lab (IEL) before the participant arrived.

On arrival, the participant was briefed about the overall experimental procedures and any questions or concerns regarding the study were addressed. Informed consent was then obtained by getting the participant’s signature on the informed consent form. The participant then completed the first part of the questionnaire containing the demographic items, items pertaining to computer usage and experience, object-spatial visual imagery scale and the Santa Barbara sense of direction scale.

The participant was then briefed about their role in the study based on the narrative transportation manipulation. Participants in the high narrative condition were told that their
part in the research was to role-play a crime scene investigator in the CSI™ game environment under development. Participants in the low narrative condition were told that their part in the research was to evaluate the aesthetic quality of the CSI™ game environment under development.

Table – 1  Distribution of participants across experimental conditions

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The participant was then taken to the seat in front of IEL large screen display and briefed about the use of joystick controls based on the steering condition. After demonstrating the use of the joystick, the participant was allowed to practice using the joystick. They were given sufficient time until he/she could move with ease around the model of the house which acted as the training environment with ease.
Once the participant was comfortable using the joystick, second instantiation of the narrative transport condition was implemented through verbal instruction detailed earlier. They went through the opening screens of the game with participants in high narrative condition focused on imagining themselves as a CSI agent. Those in the low narrative content rated the quality of graphics on four aspects. They rated the overall quality of images, choice of font, overall layout and the verbosity of the on-screen text.

Towards the end of the presentation of the opening screens, the last few slides instructed the participant about the tablet PC dashboard, thus introducing the manipulation for the guidance condition. Those in the high guidance condition were shown the tablet PC with the office layout and how they can keep track of their position in the office environment at any given time by following the position of the red circle. Those in the low guidance condition were shown the tablet PC without the office layout. Please see Appendix – C for the guidance instructions in the opening screens according to the guidance condition.

At the end of the presentation of the opening screens, the subjects were taken automatically to the office environment. Subjects navigated through the office environment for 10 minutes. Those in the high narrative condition role played a CSI agent looking for clues in the office environment and those in the low narrative condition focused on the aesthetic aspects of the office environment in addition to looking for clues as described in detail earlier.

After finishing the navigation task, the participants completed the second part of the questionnaire containing spatial presence measures, measures for spatial situation model, enjoyment and manipulation checks. The subjects also completed the puzzle task on a laptop computer which captured their spatial situation model. They were given the images of the five rooms in the office environment and a list of objects in the office environment and asked to arrange the images of rooms such that the images of adjacent rooms were adjacent to each other. Once the images of the rooms were arranged, they had to match the objects from the list to the rooms in which they were located. The rooms in the office environment
were laid out in a inverted ‘L’ shape with three rooms to the back of the lobby space and two to the right side. For any given room one point was assigned for each adjacent room that was placed correctly for a maximum of 8 points. Points were also arranged for getting the overall arrangement correct. Two points were assigned for a perfect arrangement of rooms in the correct order from left to right, one point if all the adjacencies were correct but the order from left to right was reversed. Any other arrangement was scored as zero. One point was assigned per object for correctly matching it to the room in which it was located. Thus the maximum possible score for the SSM based on the puzzle task was 16. See figure – 18 for an idea about the puzzle task.

Data analysis plan

The first set of hypotheses predicted the impact of navigability affordances and narrative transportation on spatial presence. Factorial MANCOVAs followed by four factorial ANCOVAs were used for answering hypotheses and research question, since the experiment was planned as a full factorial with four independent variables, multiple dependent variables measuring different dimensions of spatial presence, and different
control variables such as attention allocation, visual spatial imagery, suspension of disbelief and higher cognitive involvement.

The second set of hypotheses predicted the impact of navigability affordances and narrative transportation on spatial situation model. Similar to the analysis described above, a factorial MANCOVA followed by two factorial ANCOVAs were conducted to examine the hypotheses pertaining to spatial situation models.

Next hypothesis pertained to the relationship between spatial situation models and spatial presence. Multiple regression was employed to examine the impact of SSMs on spatial presence measures. Baron and Kenny’s (1986) approach was employed to examine if SSM mediated the effect of navigability affordances on spatial presence. According to Baron and Kenny (1986), for a variable M to mediate the effect of an independent variable X on a dependent variable Y, there must be a direct effect of X on M, a direct effect of X on Y and the effect of X on Y must be less when controlled for M. Baron and Kenny (1986) state that perfect mediation occurs when the independent variable has no effect on the dependent variable when controlling for the mediator.

The final research question pertained to the relationship between spatial presence and enjoyment. A multiple linear regression was carried out to answer it. A factorial ANCOVA was also conducted to examine the impact of navigability affordances and narrative transportation on enjoyment. Baron and Kenny’s (1986) approach was adopted again to see if spatial presence mediated the effect of navigability affordances on enjoyment.
Chapter – 3

Data Analysis and Results

*Index construction and preparation for data analysis*

Spatial presence was measured using four scales to capture its different dimensions – spatial self-location, possibilities for action, vection and reality judgment. Indices for these four spatial presence dimensions, were constructed by averaging individual items on the respective scales. Overall, the indexes created for *self-location* (3 items; Cronbach’s alpha = 0.90), *possibility for actions* (3 items; Cronbach’s alpha = 0.81), *vection* (4 items; Cronbach’s alpha = 0.84) and *reliability judgment* (5 items; Cronbach’s alpha = 0.94) dimensions of spatial presence had good internal consistency. Since these indices were all measuring some aspect of spatial presence, they were moderately correlated as revealed in the table – 2 given below.

*Table – 2  Bivariate correlations among spatial presence scales*

<table>
<thead>
<tr>
<th></th>
<th>Spatial self-location</th>
<th>Possibilities for action</th>
<th>Vection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possibilities for action</td>
<td>0.70***</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vection</td>
<td>0.68***</td>
<td>0.77***</td>
<td>-</td>
</tr>
<tr>
<td>Reality Judgment</td>
<td>0.73***</td>
<td>0.72***</td>
<td>0.72***</td>
</tr>
</tbody>
</table>

*** p < .0001

MANOVAs are ideal when dependent variables are moderately correlated (around |0.60|) but issues of singularity and multi-collinearity arise when the bivariate correlations are over 0.90 (Tabachnick & Fidell, 2007). Even though, all correlation coefficients were less than 0.90, precautions were taken by examining variance inflation factor (VIF) and checking if the determinant of the pooled within-cells correlation matrix is sufficiently different from
zero, whenever these indices were used in the analysis, in order to rule out multicollinearity and singularity.

Items pertaining to the spatial situation model (SSM) were averaged to create the *perceived SSM* scale (5 items; Cronbach’s alpha = 0.90) and items pertaining to enjoyment were averaged to create the enjoyment scale (5 items; Cronbach’s alpha = 0.97). Indexes were also created for the control variables by averaging items on the scale. Indices created for the subject’s *attention allocation* (3 items; Cronbach’s alpha = 0.82), *cognitive involvement* (4 items; Cronbach’s alpha = 0.85), *suspension of disbelief* (3 items; Cronbach’s alpha = 0.86), *object-imagery* (15 items; Cronbach’s alpha = 0.90) & *spatial imagery* (15 items; Cronbach’s alpha = 0.84) and *sense of direction* (15 items; Cronbach’s alpha = 0.89) also had good reliability. Descriptive statistics of the dependent, mediating and control variables used in analyses are given in table – 3.

**Table – 3  Descriptive statistics for dependent, mediating and control variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>M</th>
<th>S.D</th>
<th>Skewness (S.E. = 0.157)</th>
<th>Kurtosis (S.E. = 0.157)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP: Self-location</td>
<td>6.24</td>
<td>1.70</td>
<td>-0.59</td>
<td>-0.09</td>
</tr>
<tr>
<td>SP: Possibilities for action</td>
<td>5.77</td>
<td>1.69</td>
<td>-0.037</td>
<td>-0.39</td>
</tr>
<tr>
<td>SP: Vection</td>
<td>5.82</td>
<td>1.58</td>
<td>-0.43</td>
<td>-0.18</td>
</tr>
<tr>
<td>SP: Reality judgment</td>
<td>5.65</td>
<td>1.66</td>
<td>-0.56</td>
<td>-0.11</td>
</tr>
<tr>
<td>Perceived SSM</td>
<td>7.02</td>
<td>1.27</td>
<td>-0.86</td>
<td>0.44</td>
</tr>
<tr>
<td>Measured SSM*</td>
<td>7.55</td>
<td>4.10</td>
<td>0.62</td>
<td>-0.49</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>6.40</td>
<td>2.08</td>
<td>-0.89</td>
<td>0.25</td>
</tr>
<tr>
<td>Attention allocation</td>
<td>7.30</td>
<td>1.43</td>
<td>-1.05</td>
<td>1.33</td>
</tr>
<tr>
<td>Object imagery</td>
<td>5.94</td>
<td>1.33</td>
<td>-0.22</td>
<td>0.10</td>
</tr>
<tr>
<td>Suspension of disbelief</td>
<td>4.30</td>
<td>2.16</td>
<td>-0.07</td>
<td>-0.59</td>
</tr>
<tr>
<td>Cognitive involvement</td>
<td>6.68</td>
<td>1.47</td>
<td>-0.95</td>
<td>0.99</td>
</tr>
</tbody>
</table>

* Measured SSM was scored out of 16. Other scores were on a scale of 0 to 9.

Based on the Mahalanobis plot, one multivariate outlier was removed resulting in an overall N of 239. Each of the sixteen experimental conditions thus had 15 subjects except one, which had 14. The experiment cell sizes were thus more or less balanced and robust.
enough for analysis. Prior to each analysis described in this chapter, all assumptions were checked and ensured to be satisfactory before proceeding.

*Manipulation checks*

Manipulation check items were included in the post-experiment questionnaire to assess the effectiveness of the manipulations for each independent variable. Six items evaluating the effectiveness of the steering control manipulations (high vs. low) were additively combined to form a steering ability index (Cronbach’s alpha = 0.77). An independent samples *t* test revealed that subjects in the high steering control (M = 6.15, S.D = 1.50) perceived that the joystick controls indeed provided greater control to maneuver their movements in the office environment than those subjects in the low steering control (M = 5.02, S.D = 1.36), *t*(234) = 6.06, *p* < .0001.

Three items evaluating the effectiveness of environmental constraints manipulation (high vs. low) were averaged to form an index measuring the ease of movement through the office environment (Cronbach’s alpha = 0.60). The independent samples *t* test revealed that subjects in the high environmental constraint condition (M = 3.85, S.D = 1.57) perceived that it was less easy to move through the office environment (i.e., more constrained) compared to subjects in the low environmental constraints condition (M = 6.36, S.D = 1.32), *t*(237) = 13.39, *p* < .0001.

Five items captured the extent to which the tablet PC dashboard was useful in guiding the participant’s movement through the office environment. These items were averaged to create an index to measure the effectiveness of the guidance manipulation (Cronbach’s alpha = 0.93). Independent sample *t* test revealed that subjects in the greater guidance condition felt that they received more guidance (M = 6.47, S.D = 1.81) than subjects in the low guidance condition (M=4.33, S.D.=2.33) for locating themselves within the office environment and moving through it, *t*(235) = 7.90, *p* < .0001.
Seven items taken from the Green and Brock (2002) narrative transportation scale were used to measure the extent of narrative transportation. The scores of these items were averaged to create the narrative transportation index (Cronbach’s alpha = 0.87) to be used as a manipulation check. An independent sample t test using this index revealed that subjects assigned to the CSI role-playing task felt that they were more transported into the narrative world (M=6.45, S.D.=1.14) compared to the subjects in the graphic evaluation task (M=3.50, S.D.=1.45), t(234)=17.44, p<.0001. Above results confirm that the implementations of the independent variable levels were highly effective.

Hypotheses set – I: Impact of navigability and narrative transportation on spatial presence

\( H_1: \) The greater the steering control, the greater the spatial presence

\( H_2: \) The greater the number of environmental constraints, the greater the spatial presence

\( H_{12}: \) There will be an interactive effect of steering control and environmental constraints on spatial presence as shown below.

\( H_3: \) The greater the narrative transportation, the greater the spatial presence.

\( RQ_1: \) What is the relationship between guidance and spatial presence

The first set of hypotheses predicted that greater steering control, environmental constraints and narrative transportation will each result in greater spatial presence. Additionally, a research question was proposed about the impact of guidance on spatial presence. Spatial presence was measured on four different dimensions: self-location, possibility for action, vection and reality judgment. A factorial multivariate analysis of covariate (MANCOVA) was conducted with object imagery index, attention allocation and suspension of disbelief as covariates to evaluate above hypotheses and research question. The MANCOVA analysis revealed significant main effect for \textit{steering control}, Wilks’ \( \Lambda = 0.92 \), \( F(4, 214) = 4.55, p<.01 \), partial \( \eta^2 = 0.08 \) and a significant main effect for \textit{narrative transportation}, Wilks’ \( \Lambda = 0.92 \), \( F(4, 214) = 4.99, p<.001 \), partial \( \eta^2 = 0.09 \). The four way interaction between steering control, environmental constraints, guidance and narrative
transportation was also significant, Wilks’ $\Lambda = 0.95$, $F(4, 214) = 2.68$, $p<.05$, partial $\eta^2 = 0.05$ indicating that at the multivariate level, all independent variables had a combined effect on a linear combination of spatial-presence dimensions. Attention allocation Wilks’ $\Lambda = 0.688$, $F(4, 214) = 24.26$, $p<.0001$, partial $\eta^2 = 0.31$ and suspension of disbelief, Wilks’ $\Lambda = 0.91$, $F(4, 214) = 5.58$, partial $\eta^2 = 0.09$, were also significant predictors of spatial presence at the multivariate level.

Factorial analysis of covariance (ANCOVA) were conducted as follow-up to the multivariate analysis to examine the impact of independent variables on each of the four dimensions of spatial presence. For spatial self-location, there was a significant main effect for steering control, $F(1, 217) = 3.88$, $p=.05$, partial $\eta^2 = 0.02$. Subjects in the high steering control condition felt greater self-location in the virtual office environment (adj. $M = 6.44$, S.E. = 0.14) compared to those in the lower steering control condition (adj. $M = 6.06$, S. E. 0.14). The results also indicate that attention allocation significantly covaried with spatial self-location, $\beta = 0.58$, $t(217) = 8.05$, $p < .0001$.

For possibilities for action component of spatial presence, there were significant main effects for steering control, $F(1, 217) = 5.17$, $p < .05$, partial $\eta^2 = 0.02$ and narrative transportation, $F(1, 217) = 4.78$, $p <.05$, partial $\eta^2 = 0.02$. Subjects in the high steering control condition felt that they had greater possibilities for action (adj. $M = 6.00$, S.E. = 0.13) in the virtual environment compared to subjects in the low steering control condition (adj. $M = 5.57$, S.E. = 0.133). Contrary to expectation, subjects in the low narrative transportation condition felt that they had greater possibilities for action (adj. $M = 6.00$, S.E. = 0.136) compared to the high narrative transportation condition (adj. $M = 5.57$, S.E. = 0.14).

For the vection component of spatial presence, there were significant main effects for steering control, $F(1, 217) = 13.46$, $p < .001$, partial $\eta^2 = 0.06$ and narrative transportation, $F(1, 217) = 15.73$, $p <.0001$, partial $\eta^2 = 0.07$. Subjects in the high steering control condition reported greater vection (adj. $M = 6.14$, S.E. = 0.13) in the virtual environment compared to
subjects in the low steering control condition (adj. M = 5.57, S.E. = 0.13). Also, subjects in the low narrative transportation condition felt greater vection (adj. M = 6.19, S.E. = 0.12) while moving through the virtual environment compared to those in the high narrative transportation condition (adj. M = 5.47, S.E. = 0.13).

For reality judgment, there was a near-significant main effect for guidance, F (1,217) = 3.028, p<.1, partial $\eta^2 = 0.01$ and a significant main effect for narrative transportation, F (1, 217) = 9.79, p < .01, partial $\eta^2 = 0.04$. Subjects in the low guidance condition scored higher on the reality judgment scale (adj. M = 5.81, S.E. = 0.13) compared to high guidance condition (adj. M = 5.50, S.E. = 0.13). Again, contrary to expectations, subjects in the low narrative transportation condition scored higher on the reality judgment scale (adj. M = 5.95, S.E. = 0.13) compared to those in the high narrative transportation condition (adj. M = 5.356, S.E. = 0.131). These main effects should be considered in light of significant two-way interactions of these variables with the steering control variable.

There was a significant interaction between steering control and guidance, F (1, 217) = 4.02, p < .05, partial $\eta^2 = 0.02$ (See figure – 19). For low guidance, there was hardly any difference between high (adj. M = 5.70, S.E. = 0.18) and low steering control (adj. M = 5.92, S.E. = 0.18) in reality judgment, but for high guidance, low steering control (adj. M = 5.25, S.E. = 0.18) seemed to significantly lower perceptions of reality judgment when compared to high steering control (adj. M = 5.75, S.E. = 0.18).

Figure 19: Spatial Presence - Reality judgment: Guidance x steering control interaction
The analysis also revealed a significant interaction between steering control and narrative transportation, F (1, 217) = 3.98, p < .05, partial $\eta^2 = 0.02$ (See figure below). For high narrative transportation, there was not much difference between high (adj. M = 5.25, S.E. = 0.18) and low (adj. M = 5.47, S.E. = 0.18) steering control in terms of reality judgment. However, for low narrative transportation, high steering control (adj. M = 6.20, S.E. = 0.18) enhanced perceptions of reality judgment compared to low steering control (adj. M = 5.70, S.E. = 0.18).

![Steering x Narrative Transportation Interaction](image)

Figure 20: Spatial Presence - Reality judgment: Narrative x steering control interaction

Summary of spatial presence results

Results of the MANCOVA and the follow up ANCOVA analyses revealed overwhelming support for $H_1$. Steering control had a significant main effect on the self-location, possibilities for action and vection components of spatial presence and had significant two-way interactions with narrative transportation and guidance on reality judgment.

$H_2$ was not supported for any dimension of spatial presence indicating that greater environmental constraints had no impact on spatial presence formation. It was expected that there would be an addictive effect of greater steering control and greater environmental
constraints on spatial presence. Since the interactive effect of steering control and constraints on spatial presence was not significant, H₁₂ was not supported.

Narrative transportation had a significant impact on possibilities for action, vection and reality judgment dimensions of spatial presence. However, the results were in the direction opposite to those hypothesized, with lower narrative transportation eliciting better spatial presence than high narrative transportation, leading us to reject H₃.

For RQ1, analysis revealed that guidance had no effect on spatial presence dimensions except reality judgment. The results of the main effect for guidance as well as the interactive effect with the steering control indicate that high guidance has a negative effect on reality judgment. Overall findings for spatial presence can be summarized in the following figure.

S = Significant  NS = Not significant  S* = Significant results in the direction opposite to that predicted

Figure – 21  Summary of spatial presence results
Hypotheses set – II: Impact of navigability and narrative transportation on formation of spatial situation model (SSM).

The second set of hypotheses pertained to the impact of steering control, guidance and narrative transportation on the formation of spatial situation models. It was expected that there would be a positive relationship between the independent variables and SSM.

\[ H_4: \quad \text{The greater the steering control, better the SSM.} \]

\[ H_5: \quad \text{The greater the guidance, better the SSM.} \]

\[ H_6: \quad \text{The greater the narrative transportation, better the SSM.} \]

Initial analysis revealed that there was hardly any correlation, \( r = -0.02, p = 0.82 \), between the self-reported SSM score and the measured SSM. Therefore these two measures were chosen to be included as separate terms in all the analyses instead of combining them or choosing one over the other. Including these as two separate terms also would provide a more nuanced understanding of the role played by both the perceived richness of the SSM (self-reported SSM) and the accuracy of the SSM with respect to the actual media representation (measured SSM).

To test the above hypotheses pertaining to SSM, ANCOVAs were conducted for perceived and measured SSM. The ANCOVA analysis for the self-reported SSM revealed a significant main effect for guidance, \( F(1, 219) = 4.89, p < .05 \), partial \( \eta^2 = 0.02 \). Subjects in the greater guidance condition reported lower SSM (adj. M = 7.24, S. D. = 1.11) compared to the subjects in the lower guidance condition (adj. M = 6.79, S. D. = 1.38). The analysis also revealed a moderate main effect for narrative transportation, \( F(1, 219) = 2.93, p < .1 \), partial \( \eta^2 = 0.01 \). Subjects in the high narrative transportation condition reported lesser SSM (adj. M = 7.00, S. D. = 1.11) than subjects in the low narrative transportation condition (adj. M = 7.03, S. D. = 1.42). The results indicate that for the self reported SSM measure, the hypotheses were not supported and are in the opposite direction.
ANCOVA analysis for measured SSM (through the puzzle task) also revealed significant main effect for guidance, $F(1, 219) = 7.960$, $p < .01$, partial $\eta^2 = 0.035$ and for narrative transportation $F(1, 219) = 17.71$, $p < .0001$, partial $\eta^2 = 0.08$. Subjects in the high guidance condition scored higher on SSM puzzle task (Mean = 8.21, S.D. = 4.22) compared to subjects in the low guidance condition (Mean = 6.81, S.D. = 3.82). The results indicate that for measured SSM, the hypotheses for formation of SSM were partially supported. While guidance and narrative transportation had significant impact on SSM, steering control and environmental constraints did not significantly impact the formation of SSM.

Summary of SSM results

Above results indicate that steering control had no significant effect on formation of spatial situation and thus rejecting $H_4$. While guidance and narrative transportation had significant impact on the formation of spatial situation model, they were in opposite directions for the self-reported SSM and the measured SSM. While low guidance and low narrative transportation resulted in better self-reported SSM scores, high guidance and high narrative transportation resulted in better scores on measured SSM using the spatial puzzle task. Hence hypotheses $H_5$ and $H_6$ are partially supported as shown in figure 22 and figure 23.

Figure – 22 Impact of guidance and narrative transportation on SSM

$S =$ Significant

$S^* =$ Significant results in the direction opposite to that predicted
Hypotheses set – III: Impact of SSM on spatial presence dimensions

H7: The better the SSM, greater the spatial presence.

A series of multiple regressions were run with both perceived SSM (self-reported) and measured SSM (using puzzle task) as independent variables against each dimension of spatial presence: self location, possibilities for action, vection and reality judgment. Based on the Wirth et al. (2007) two step-model of spatial presence formation, suspension of disbelief and higher cognitive involvement were expected to influence spatial presence formation and therefore included in each model.

The first multiple regression analysis was performed with self-location dimension of spatial presence as the dependent variable, perceived SSM, measured SSM, cognitive involvement and suspension of disbelief as predictors. Analysis revealed that the model significantly predicted self-location, $F(3,235) = 57.179, p < .0001, R^2 = 0.422$, adjusted $R^2 = 0.415$. Standardized regression coefficients, correlation coefficients, t-values and their significance levels are given in the table – 4 below. The regression results indicate that both self-reported ($t = 4.562, p < .001$) and measured SSM ($t = -2.318, p < .05$) significantly predicted self-location. The SSM measures together with cognitive involvement accounted
for 41.5% of overall variance. As expected, perceived SSM positively predicted spatial self-location with increase in perceived SSM leading to greater self-location. However, the interesting aspect of the analysis was that measured SSM was negatively related to self-location. Increase in measured SSM scores resulted in a decrease in the level of self-location.

Table – 4  SSM and Spatial Presence: Self-Location

<table>
<thead>
<tr>
<th>Predictors</th>
<th>β</th>
<th>correlation coefficient</th>
<th>partial correlation coefficient</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived SSM</td>
<td>.313</td>
<td>.581</td>
<td>.285</td>
<td>4.562***</td>
</tr>
<tr>
<td>Measured SSM</td>
<td>-.116</td>
<td>-.091</td>
<td>-.150</td>
<td>-2.318*</td>
</tr>
<tr>
<td>Cognitive Involvement</td>
<td>.386</td>
<td>.593</td>
<td>.344</td>
<td>5.608***</td>
</tr>
</tbody>
</table>

*** p < .001  ** p < .01  * p < .05

The second multiple regression analysis was performed to assess the impact of SSM on the possibilities for action dimension of spatial presence with perceived SSM, measured SSM, cognitive involvement and suspension of disbelief as predictors. Analysis revealed that the overall model significantly predicted participants’ perception of possibilities for action, F(4,233) = 47.675, p < .0001, R² = 0.450, adj. R² = 0.441. Standardized regression coefficients, correlation coefficients, t-values and their significance levels are given in the table – 5 below. The regression results indicate that both perceived (t = 4.924, p < .0001) and measured SSM (t = -3.067, p < .01) significantly predicted perceived possibilities for action. The overall model accounted for 44.5% of the total variance. Results indicate that perceived SSM positively predicted perceived possibilities for action with greater self-reported SSM scores leading to greater perceived possibilities for action in the virtual environment. However, measured SSM was negatively related to perceived possibilities for action. Increase in measured SSM scores decreased perceived possibilities for action.
A multiple regression analysis was performed to assess the impact of SSM on the vection dimension of spatial presence with perceived SSM, measured SSM, cognitive involvement and suspension of disbelief as predictors. Analysis revealed that the overall model significantly predicted participant’s perception of possibilities for action, $F(3, 235) = 57.94$, $p < .0001$, $R^2 = 0.43$, adj $R^2 = 0.42$. Standardized regression coefficients, correlation coefficients, t-values and their significance levels are given in the table – 6 below. The regression results indicate that while perceived SSM ($t = 5.16$, $p < .0001$) significantly predicted vection, measured SSM ($t = -1.56$, $p > .1$) did not significantly impact vection. The overall model accounted for 42.5% of the variance. Results suggest that self-reported SSM positively predicted vection with greater self-reported SSM leading to greater vection. However, measured SSM was negatively related to vection, even though the relationship was not significant.

**Table – 6  SSM and Spatial Presence: Vection**

<table>
<thead>
<tr>
<th>Predictors</th>
<th>$\beta$</th>
<th>correlation coefficient</th>
<th>partial correlation coefficient</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived SSM</td>
<td>.354</td>
<td>.599</td>
<td>.319</td>
<td>5.163***</td>
</tr>
<tr>
<td>Measured SSM</td>
<td>-.078</td>
<td>-.055</td>
<td>-.101</td>
<td>-1.559</td>
</tr>
<tr>
<td>Cognitive Involvement</td>
<td>.354</td>
<td>.591</td>
<td>.318</td>
<td>5.147***</td>
</tr>
</tbody>
</table>

*** $p < .001$    ** $p < .01$    * $p < .05$
A multiple regression analysis was performed to assess the impact of SSM on the reality judgment dimension of spatial presence with perceived SSM, measured SSM, cognitive involvement and suspension of disbelief as predictors. Analysis revealed that the overall model significantly predicted participant’s perception of reality judgment, $F(4, 233) = 14.11, p < .0001, R^2 = 0.41, \text{adj } R^2 = 0.40$. Standardized regression coefficients, correlation coefficients, t-values and their significance levels are given below in table – 7. The regression results indicate that both perceived SSM ($t = 4.372, p < .0001)$ and measured SSM ($t = -3.43, p < .01$) significantly predicted reality judgment. The overall model accounted for 40.4% of the total variance. Like in the case of other dimensions of spatial presence, perceived SSM positively predicted perceptions of reality judgment with greater perceived SSM scores leading to better reality judgment. Again, measured SSM was negatively related to perceptions of reality judgment. Increase in measured SSM scores decreased the perceptions of reality judgment.

<table>
<thead>
<tr>
<th>Predictors</th>
<th>$\beta$</th>
<th>correlation coefficient</th>
<th>partial correlation coefficient</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived SSM</td>
<td>.304</td>
<td>.542</td>
<td>.275</td>
<td>4.372***</td>
</tr>
<tr>
<td>Measured SSM</td>
<td>-.173</td>
<td>-.151</td>
<td>-.219</td>
<td>-3.426**</td>
</tr>
<tr>
<td>Cognitive Involvement</td>
<td>.352</td>
<td>.544</td>
<td>.314</td>
<td>5.045***</td>
</tr>
<tr>
<td>Suspension of disbelief</td>
<td>.186</td>
<td>.170</td>
<td>.236</td>
<td>3.706***</td>
</tr>
</tbody>
</table>

*** $p < .001$ ** $p < .01$ * $p < .05$

**Summary of results for SSM – spatial presence relationship**

Overall, the results described above indicate that self-reported SSM scores significantly predicted all four dimensions of spatial presence with better self-reported SSM scores resulting in increased spatial presence. While the impact of self-reported SSM scores
on the spatial presence dimensions were in the expected direction, the relationship between measured SSM scores and the spatial presence dimensions were in the opposite direction. Overall, increase in measured SSM score resulted in lower scores on the four spatial presence dimensions. Thus hypothesis H7 was partially supported.

Testing for SSM mediating spatial presence

Results described thus far show that guidance and narrative transportation had significantly predicted formation of SSM meeting the first step described in Baron and Kenny’s (1986) three-step model for checking mediation. Also steering control, narrative transportation, and guidance predicted one or more of the spatial presence dimensions meeting the second criterion for mediation. To test if SSM mediated the impact of any of the independent variables on any of the four dimensions of spatial presence, in accordance with Baron and Kenny’s (1986) third step, the self reported and measured SSM scores were added as additional covariates in MANCOVA and ANCOVA analysis described above.

At the multivariate level, addition of SSM scores as a covariate reduced the overall multivariate significance level from $p = \text{.0007} \ [\text{Wilks' } \Lambda = 0.92, \ F (4, 214) = 4.99, \ \text{partial } \eta^2 = 0.09]$ to $p = \text{.003} \ [\text{Wilks' } \Lambda = 0.93, \ F (4, 212) = 4.14, \ \text{partial } \eta^2 = 0.07]$. There was no noteworthy change in the significance level of steering control and the four-way interaction. When the two SSM scores were added to the univariate models, the only noticeable change was in the significance level for narrative transportation variable for models predicting possibilities for action and vection dimensions of spatial presence. When the self-reported and measured SSM scores were added to the model predicting possibilities for action, narrative transportation was rendered non-significant, $F (1, 215) = 0.95, \ p = .33, \ \text{partial } \eta^2 = 0.004$. This indicates that the relationship between narrative transportation and the possibilities for action dimension of spatial presence is fully mediated by the formation of spatial situation model.
After addition of SSM scores to the model predicting vection, narrative transportation was reduced in strength but still significant, $F(1, 215) = 11.67, p = .0008$, partial $\eta^2 = 0.05$. This suggested partial mediation. A follow-up Sobel test indicated that the partial mediation was not significant (Sobel test statistic = 1.63, $p > .1$).

**RQ2 – Spatial presence and enjoyment**

A multiple linear regression was conducted to examine the impact of the four spatial presence dimensions on enjoyment. Analysis revealed that the final model significantly predicted enjoyment, $F(2, 235) = 54.24, p < .0001$. $R^2$ for the model was 0.32 and adjusted $R^2$ was 0.31. The results revealed that vection ($t = 2.67, p < .01$) and reality judgment ($t = 5.13, p < .0001$) significantly predicted enjoyment. Table given below displays the Standardized regression coefficients, correlations and t-values with their level of significance. The overall model accounted for 31.0% in shared variability. Results indicate that increased levels of vection and better reality judgment leads to significantly greater enjoyment.

**Table – 8  Spatial presence dimensions predicting enjoyment**

<table>
<thead>
<tr>
<th>Predictors</th>
<th>$\beta$</th>
<th>correlation coefficient</th>
<th>partial correlation coefficient</th>
<th>$t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>vection</td>
<td>0.206</td>
<td>0.489</td>
<td>0.172</td>
<td>2.67*</td>
</tr>
<tr>
<td>reality judgment</td>
<td>0.396</td>
<td>0.543</td>
<td>0.317</td>
<td>5.13***</td>
</tr>
</tbody>
</table>

*** $p < .0001$  * $p < .1$

**Supplementary analysis**

Navigability, narrative transportation and Enjoyment

A factorial analysis of covariance (ANCOVA) was conducted to examine the impact of independent variables on enjoyment. The results indicated there was a significant main effect for narrative transportation, $F (1, 222) = 11.76, p<.001$, partial $\eta^2 = 0.05$. Subjects in the high narrative transportation reported greater enjoyment in the virtual office environment (adj.
M = 6.86, S.E. = 0.19) compared to those in the low narrative transportation condition (adj. M = 5.94, S. E. = 0.19).

ANCOVA analysis described earlier in the results section indicated that relationship between narrative transportation and vection as well as between narrative transportation and reality judgment were significant (from first set of results). Also it was shown that the vection and reality judgment significantly predicted enjoyment. The results indicate that two of the three conditions for spatial presence to mediate the effect on enjoyment were met according to Baron and Kenny’s (1986) approach. The third step of the analysis was conducted to see if either vection or reality judgment mediated the effect of narrative transportation on enjoyment. A factorial ANCOVA was conducted with the four independent variables as well as vection and reality judgment as covariates. The results showed that narrative transportation term was even more significant, thus providing evidence for lack of mediation.

Summary of results

The analyses indicate that steering control and narrative transportation significantly predicted most of the spatial presence dimensions. As predicted, greater steering control led to greater spatial presence. However, the impact of narrative transportation on spatial presence was counter to our hypotheses. In general, greater narrative transportation led to lower spatial presence.

The impact of independent variables on SSM revealed that both guidance and narrative transportation significantly predicted SSM. However, the results for self-reported SSM and measured SSM (puzzle task scores) were in the opposite directions. For the measured SSM, as hypothesized, greater guidance and greater narrative transportation led to better SSM. However, for self reported SSM, greater guidance and greater narrative transportation resulted in lower SSM.

The results show that both self-reported and measured SSM significantly predicted spatial presence, but in opposite directions. Better scores on the self-reported SSM were
associated with greater spatial presence, but higher scores on measured SSM were associated with lower spatial presence.

The two step model of spatial presence formation proposed by Wirth et al. (2007) suggested that formation of SSM mediated spatial presence. Overall, the results did not support this model. The only exception was in the case of the impact of narrative transportation on the possibilities for action dimension of spatial presence, where SSM did indeed mediate the relationship.

The results also indicate that vection and reality judgment dimensions of spatial presence significantly predicted enjoyment. Again, as one would expect greater narrative transportation led to greater enjoyment.
Chapter – 4

Discussion

This study sought to understand spatial presence in virtual environments as a function of navigability affordances. To this end, navigability was first explicated and its components identified. The sub-components of steering control, environmental constraints and guidance, along with narrative transportation, were then manipulated in a controlled experiment, and the impact on different spatial presence dimensions measured. As one of the first in-depth experimental investigations of navigability and spatial presence in virtual environments, this study revealed that steering control and narrative transportation significantly impacted spatial presence. While the impact of steering control on spatial presence was along expected lines, the impact of narrative transportation on spatial presence was counter-intuitive. While greater steering control enhanced feelings of spatial presence, greater narrative transportation resulted in lower spatial presence. As for the other two independent variables in the study, environmental constraints did not have a significant impact on any of the spatial presence dimensions, and guidance only affected the reality-judgment dimension of spatial presence.

This chapter interprets these findings, elaborates possible mechanisms underlying them and summarizes theoretical implications for presence research. Practical implications of these findings for entertainment media, especially interactive video games, and for spatial visualization are also discussed. The chapter concludes by identifying limitations of the current study and laying out directions for future research.
Interpretation of findings

Steering control and spatial presence

The results from the study confirmed that steering control had a significant and direct effect on all four dimensions of spatial presence – spatial self location, possibilities for action, vection and reality judgment. Since subjects were unaware of the relative difference between high and low steering control conditions, the results indicate that even a small difference in navigational affordance can have a huge impact on spatial-presence formation. While this effect was anticipated in the hypotheses, it is important to explore how steering control may affect each dimension of spatial presence. Spatial self-location and reality judgment dimensions capture spatial presence from an immersion point of view whereas possibilities for action and vection dimensions capture spatial presence from an activity based approach. Significant results for spatial self-location and reality-judgment dimensions of spatial presence indicate support for immersion based approaches for spatial presence. Significant results for the possibilities for action and vection dimensions indicate support for activity-based approaches to spatial presence.

Lee et al. (2004) argue that spatial presence arises from an unconscious effort to register oneself consistently in a given virtual environment. Visual reasoning associated with spatial presence formation is considered to be a perceptual bottom-up processing employing both “what” (object discrimination using low-level vision) and “where” (landmark discrimination/object localization using high-level visual processing) pathways in our brain’s visual system (Celesia, 1997). Movement through space – real or virtual, activates both pathways. Better steering control enhances movement through the virtual environment and can provide additional sensory spatial cues such as motion parallax. A series of experiments reported by Lee et al. (2004) shows that a bottom-up perceptual process gathers spatial cues to actively place and register the user in the virtual environment. This is consistent with Slater’s (2003) characterization of presence resulting from ‘form’ factor as opposed to ‘content’ factors. Simulated sensory data activates perceptual systems similar to a
corresponding real-life situation creating a coherent space to locate oneself in and even afford possibilities to act (Slater, 2003). Greater steering control presents the user with more perceptual cues that can help the user self-locate in the virtual environment. In the current study, greater steering control afforded the user a greater range of movement possibilities at any given time compared to lesser steering control, resulting in greater spatial feedback. Thus, it met Steuer’s (1992) argument that range is an important interactivity characteristic that can lead to greater spatial presence. Interactivity here is seen as the ability of the users to modify either form and/ or content of the virtual environment (Steuer, 1992). Greater steering control resulted in greater ability to move or modify user viewpoint in the virtual environment with respect to both location and orientation. In this study, viewpoint modification was thus the main sensor mechanism within the virtual environment which was devoid of auditory, tactile or other sensory mechanisms. Greater ability to move within the virtual environment by modifying the user viewpoint resulted in a greater range of spatial feedback extending to the extrapersonal space. With greater steering control, users could progressively adapt their locomotion in the virtual environment based on spatial feedback, leading to better representation of the efference-afference linkage and thereby greater distal attribution. This suggests an increased perceptual linkage between the user and the virtual environment enhancing their sense of ‘being there’ and ‘acting there’ leading to better self-location as well as their perceived possibilities for action.

Findings also indicated that greater steering control led to greater sense of self-motion (vection). This indicates an elaboration of the mechanism of spatial presence formation as resulting from visual feedback and efference-afference linkage. During spatial perception, the user assumes a “rest frame”, a particular reference frame presumed to be stationary so as to judge position, orientation and motion (Harm, Parker, Reschke, & Skinner, 1998; Prothero, 1998). According to Prothero (1998), spatial presence in any given environment reflects the degree to which that environment affects the rest frame. Riecke and Schulte-Pelkum (2006) have shown that a naturalistic and globally consistent virtual
environment provides subjects with a stable rest frame leading them to perceive self-motion rather than movement of virtual images. Higher vection scores also indicate that participants having greater steering control have a greater tendency to treat the virtual environment as a real-world like stable reference frame leading to greater spatial presence. Thus a strong feeling of self-motion or vection can be a possible mediator of spatial presence in navigable environments. Baron and Kenny’s (1986) procedure was used to test whether vection mediated the impact of steering control on spatial self-location and possibilities for action. Earlier, in the results section, details of the significant impact of steering control on vection were described. Bi-variate regressions revealed the vection significantly predicted both spatial self location (t= 14.12, p<.0001) as well as possibilities for action (t= 18.77, p<.0001). Vection accounted for 45.45% of the overall variance in self-location and 59.62% of the overall variance in possibilities for action. When vection was added as covariate, steering control was rendered non-significant in the model predicting self-location as well as the one predicting possibilities for action. These results indicate that vection fully mediates impact of steering control on spatial self-location and possibilities for action, lending support for the alternative explanation. Future research can further explore the relationship between vection and other spatial presence dimensions.

In the literature review, while hypothesizing the impact of steering control on spatial presence, the importance of viewpoint movement was discussed. It was suggested that the nature of viewpoint movement in the virtual environment and the resulting optic flow patterns could influence perceptions of self-motion and spatial presence. Findings from the study appear to support that idea. Lecuyer, Burkhardt, Henaff and Donikian (2006) have shown that viewpoint oscillations, particularly along the vertical axis, mimic head movements during walking and can considerably improve the sensation of walking in a virtual environment. Also, optic flow patterns which cover a large field of view have been shown to induce vection (Hettinger, 2002). In the greater steering control condition, subjects had the additional ability to tilt the camera up and down similar to looking up or down in the real world as well as slide
sideways. The greater affordance for steering thus could have resulted in greater optic flow leading to greater vection and better reality judgment of movement.

While steering control significantly impacted spatial presence, there was no significant difference between high and low steering control for both perceived and measured spatial situation model. This indicates that one of the conditions for SSM to mediate the effect between steering control and spatial presence according to Baron and Kenny (1986) is not met. Thus we did not find support for the 2-step model of spatial-presence formation proposed by Wirth (2007) in the context of steering control. However, this does not indicate a lack of formation of SSM. Out of a maximum self-reported score of 9, the perceived SSM scores were high for both low (mean = 7.00, S.D. = 1.23) and high (mean = 7.03, S.D. = 1.30) steering control conditions. Out of a maximum possible score of 16, the measured SSM scores were also respectable for both low (mean = 7.56, S.D. = 4.06) and high (mean = 7.53, S.D. = 4.14) steering control conditions. In summary, findings suggest that spatial presence as a function of steering control occurs through a bottom-up process, building up from low level sensory cues.

Environmental constraints and spatial presence

The findings did not support the hypothesis that greater number of environmental constraints analogous to the real world will lead to greater spatial presence. This was despite the indication that the manipulation of environmental constraints was successful. This suggests that the media-equation approach to spatial presence formation through application of folk-physics reasoning module (innate schemas of causal relationship in the physical world) proposed by Lee (2004b) may not be true. However, this finding needs to be interpreted with caution. In the current study, the environmental constraints were operationalized through activation of collision. In the greater constraint condition, in addition to restricting the user movement to the ground plane, movement through solid objects such as walls was blocked. In the low constraint condition, while the user movements were
restricted to ground plane, they could move through solid walls (i.e., collision is absent). Addition of constraints perhaps affected movement of users, forcing them to position and orient themselves better to pass through doors and narrow spaces. However, the only feedback that was available for environmental constraints was through the visual modality. In the high-constraints condition, internal partition walls and other solid walls stopped the user’s forward motion, until he or she turned around. In the low-constraint condition, they could pass straight through a solid wall. Since the thickness of partition walls (many made of glass) were thin, the visual feedback when passing through them lasted only momentarily and may have been too feeble to disrupt the experience to cause a break in presence. Since there was no feedback from non-visual modalities in this study, and the visual feedback was minimal, the environmental constraints implemented through collision many not have been strong enough to impact spatial presence.

**Guidance and spatial presence**

Guidance had impact only on the reality-judgment dimension of spatial presence. The results indicate that presence of guidance was detrimental to reality judgment. The literature review section of this study speculated how guidance tools had the potential to both help and hinder spatial presence formation. As discussed earlier, guidance tools such as the dashboard used in this study could be seen as an external element introduced into the office environment decreasing realism and thereby its believability. The constantly updating location marker on the tablet PC dashboard could have narrowed user attention from the larger office environment and focused it more on the dashboard. The guidance tool included a map displaying current location at any given time in the office environment. By providing a survey knowledge of the environment, the exocentric nature of the representation could have potentially hampered the efforts to self-locate within the office environment. A two-way interaction effect between guidance and steering control indicated that presence of guidance feature further lowered realism perception of the office environment in the low steering
control condition. Previous section discussed how low steering control condition lowered the level of realism for movement due to lower degrees of freedom. Inclusion of guidance tools seems to further reduce the perceived realism of the actions in the office environment.

**Guidance and SSM**

In this study, SSM was measured in two ways – a subjective self reported measure (perceived SSM) and an objective measure through a spatial puzzle task (measured SSM). Results indicated that the impact of guidance on perceived and measured SSM were in opposite directions. Contrary to prediction, high guidance resulted in lower scores for perceived SSM compared to low guidance. On the other hand, as expected, high guidance led to better scores on the measured SSM.

While unexpected, these contradictory results nevertheless offer interesting insights into the impact of guidance tools in spatial perception in virtual environments. Presence of a constantly updating guidance feature could have directed disproportionate amounts of attention to the dashboard, leaving limited attentional resources for processing direct spatial cues from the environment. This could have limited bottom-up processing of spatial cues, giving subjects the impression that they did not gain a good spatial understanding of the office environment, leading to lower scores on perceived SSM. Also, the very presence of a guidance dashboard could have cued complexity of the given space, limiting the subject’s confidence about spatial understanding. However, the dashboard presented subjects with a survey knowledge (highest order spatial information) of the office environment and did indeed attract subjects’ attention (as revealed in the successful manipulation check). Subjects in the high guidance condition thus received a top-down view of the spatial organization, leading to better scores in the measured SSM task.

In the low guidance condition, the only source of spatial information was the cues obtained through direct movement in the office environment. Since the dashboard did not take up much attentional resources, the subjects had more resources to process the spatial
cues directly from the environment. While this improved confidence about their knowledge of spatial organization, actual encoding of spatial information, especially at the survey knowledge level, was perhaps limited, leading to lower scores on the measured SSM.

**Narrative transportation and spatial presence**

In the literature review, it was predicted that greater narrative transportation can create stronger expectation hypothesis that the virtual environment is the primary ego reference frame leading to greater spatial presence. Based on the situated cognition perspective, spatial presence was also discussed as being rooted in the narrative the subject finds himself in. Greater awareness of navigational situation with respect to purpose, goals and expected actions was predicted to lead to greater spatial presence. Results revealed that narrative transportation had a significant impact on the possibilities for action, vection and reality judgment. Contrary to expectation, subjects in the greater narrative transportation condition reported lower scores for the above three dimensions of spatial presence. Also, it was found that spatial situation model scores mediated the impact of narrative transportation on the possibilities of action dimension. There are a couple of potential reasons why narrative transportation produced counter-intuitive results.

Carassa, Morganti and Tirassa (2005) suggest that the landscape of affordances for action is not merely shaped by the constraints imposed by the environment and the physical capabilities of the actor but also influenced by the actors’ motives, interests and long term goals. In the current study, putting the subjects in the high narrative condition into a CSI role-playing mode might have led them to focus their interest narrowly on the task of searching for clues. By focusing more on identifying potential clues and extending the narrative rather than processing spatial cues, they probably felt less spatially present. Also the range of possible actions could have been limited to those pertaining to the clues when looked through the eyes of a CSI.
**Narrative transportation and SSM**

Similar to guidance, narrative transportation also differed in the impact on perceived and measured spatial situation models. Contrary to prediction, subjects in the high narrative transportation condition reported lower scores on perceived SSM compared to those in the low narrative transportation condition. However, subjects in the high narrative transportation condition reported higher scores on measured SSM as expected. The findings also suggest that both perceived and measured SSM mediated the impact of narrative transportation on the possibilities for action dimension of spatial presence. However, in both cases, greater narrative transportation led to lower possibilities for action. These results again indicate how spatial cues are processed and interpreted differently in different navigational situations. In the high narrative transportation, spatial cues were perhaps processed from an objective point of view, analyzing it as another piece of the crime puzzle rather than locating oneself in the office environment from a subjective point of view. Since high narrative transportation led to greater measured SSM, this suggests that subjects were actually learning about the space. However, since this spatial understanding was used primarily for the purpose of solving the crime, they were not conscious of this understanding and reported lower scores for perceived SSM. Cognitive resources of subjects in the low narrative condition were not tied down in solving the crime as a CSI agent and could explore the space from a more subjective point of view. This may have given them the impression that they understood the space better and therefore reported better scores for perceived SSM.

**Theoretical implications**

*Role of spatial situation model in spatial presence formation*

The current study did not find strong support for SSM mediating spatial presence formation. Results indicated that SSM did not mediate the impact of navigability affordances on spatial presence formation. In fact, when SSM measures were added as a covariate, the
impact of some of the navigability affordances on spatial presence became stronger. This calls into question the universal validity of Wirth et al.’s (2007) 2-step model of spatial presence, at least within the context of navigable 3-dimensional media. Based on the findings, it might be reasonable to assume that active construction of a spatial situation model is not necessary for the participants to locate their primary ego-reference frame in a navigable 3-dimensional media such as virtual reality. In other words, formation of a spatial situation model may not be necessary for spatial presence formation in environments that offer direct spatial cues and dynamic visual feedback. Wirth et al.’s (2007) two-step model may need to be modified to specify boundary conditions where SSM formation is a necessity for spatial presence – for example in modalities lacking direct spatial cues such as print. The results suggest that SSM only mediated the effect of narrative transportation on the possibilities-for-action dimension of spatial presence. Greater narrative transportation led to greater measured SSM, but still resulted in lower spatial presence. This suggests that SSM formation could use up cognitive resources and thus be counter-productive for spatial presence formation in an already spatialized environment.

Given that the predictions of spatial presence by perceived and self-reported SSM were in the opposite directions and since SSM did not mediate the navigability affordances, it is important to further flesh out the concept of spatial situation models. Before we can gain a more accurate understanding of the role of SSM in spatial presence formation, two issues need to be addressed. The first issue is that SSM need to be placed in the context of other situation models. The second issue pertains to measurement of SSM.

Situation models arising out of media narratives are multi-dimensional. In addition to spatial situation model, other dimensions include time, causation, motivation and protagonist (Zwaan et al., 1998). As the media narrative unfolds, users are assumed to continuously keep track of when (time), why (causation and motivation), who (protagonist) as well as the where aspects of the narrative (Zwaan et al., 1998). Thus a complex narrative requires a media user to constantly update these multiple situation models which can be a big drain on
cognitive resources. Wirth et al (2007) argue that even if the SSM is formed, additional
cognitive and perceptual processes are required for spatial presence to occur. Even if a
strong SSM is formed, if cognitive resources are tied up in processing and updating other
dimensions of the situation model, formation of spatial presence might be hampered. Thus
when narratives are involved, it may be important to capture other dimensions of the
situation model, to better understand the specific role of SSM in spatial presence formation.

Wirth et al. (2007) suggest that media users continually update their SSMs by
examining the congruence of the SSM with the perceived spatial environment. However the
measures for SSM used in this study did not tap into the moment-to-moment editing of SSM.
Items measuring perceived SSM were taken from the SSM scale developed by Vorderer et
al. (2004b) can be seen more as an overall measure of confidence of the formation of a
spatial situation model. However, it did not take into account either the accuracy of the
spatial situation model or its richness. The spatial puzzle task was used in the study to
capture to accuracy of the spatial situation model and relied on recall memory. Both these
measures are retrospective in nature and do not capture the dynamic nature of a constantly
evolving SSM. It may be the case that spatial presence occurs as a result of the media
user’s attempt to register oneself into the constantly updating SSM. Future research on
spatial situation models and spatial presence should capture the dynamic nature of the SSM
by using think-aloud protocols or psychophysiological measures such as EEG in order to tap
into brain activity resulting from spatial processing.

Heuristic vs. systematic processing

It is important to examine the broad cognitive process underlying spatial presence
formation before more specific or elaborate mechanisms can be described. , According to
the elaboration likelihood model (ELM) proposed by Petty and Cacioppo (1986), there are
two cognitive paths – a central, more cognitively effortful path and a peripheral, less effortful
path relying on cues, for processing media messages. A similar distinction is made by the
heuristic-systematic model (Chaiken, 1987), where the systematic path refers to logical-
analytical processing of the media content and the heuristic path relies on heuristics or
mental shortcuts based on prior experience. Most prior research on presence does not
explicitly discuss presence from heuristic-systematic perspective with the possible exception
of Sundar (2008). There are numerous examples of presence mechanisms and definitions
which fall into either path. For example, presence as “willing suspension of disbelief” alludes
to a more systematic processing and the “perceptual illusion of non-mediation” suggests a
peripheral or heuristic processing. It may be possible that both paths may be activated during
presence formation, even if one path may be stronger than the other depending on the
context. Sundar, Oeldorf-Hirsch & Garga (2008) presents a cognitive heuristics approach to
presence research rooted in technological affordances of modality (M), agency (A),
interactivity (I) and navigability (N). The MAIN model by Sundar (2008) propose that these
four affordances cue cognitive heuristics pertaining to user perceptions of content, including
an evaluation of presence. For example, the modality affordance can cue the realism
heuristic when the virtual environment is representationally isomorphic with a corresponding
real world, thereby contributing to greater presence. This study may be seen as an
examination of spatial presence as a function of the navigability component of MAIN model

Results from this study, especially the effect of steering control on spatial presence
dimensions and guidance on spatial situation model are indicative of heuristic processing
triggered by different cues. For example, viewpoint movements analogous to those in real
world (look up and down, turn around etc) might have triggered a “similarity” heuristic making
it easier to self locate in the virtual environment. The tablet PC dashboard with the guidance
feature could have triggered a “complexity” heuristic resulting in lower scores on perceived
SSM. Understanding the relative contributions of the systematic and heuristic processing for
spatial presence formation will further our theoretical understanding of spatial presence as
well as offer guidelines for design and development of related technology.
**Limited capacity model of mediated message processing**

In presence research, it is commonly believed that more sensory immersion and greater cognitive involvement are good. However, findings from this study pertaining to narrative transportation and guidance suggest capacity limitations in spatial presence formation. This is consistent with the limited capacity model of mediated message processing put forth by Lang (Lang, 2000) who identifies three components of information processing: encoding, storage and retrieval. Lang’s (2000) model suggests that people have limited mental resources. When one of the three components of information processing take up quite a bit of resources, other components may not receive adequate resources. The capacity limitation in spatial presence formation is best illustrated in the case of narrative transportation’s significant negative impact on vection: It is well known that vection arises primarily through a bottom-up process from visual cues. In the high narrative transportation condition, since the user is focused on solving the crime, cognitive resources are tied up in encoding and retrieving clues related to solving the crime, leaving scant resources for encoding and processing motion cues. Capacity limitations inhibit processing of motion cues by privileging content-related cues which are motivationally driven by searching for clues. This leads to a lower sense of vection or self-motion. Findings from this study indicate that any model of spatial presence formation should take into account the capacity limitations for information processing to be meaningful. This is important for developing theories of spatial presence that are meaningful for technological implementation.

**Methodological implications**

In terms of methodological innovation, one modest contribution made by this study is to expand the variable-centered approach of Nass and Mason (1990). They have identified two broad approaches to technology research – box centered and variable-centered. The box-centered approach treats technology as a monolithic entity whereas the variable-
centered approach breaks down a technology into its component variables and their corresponding values (Nass & Mason, 1990). The advantage of the variable-centered approach is that the findings for a given variable can be generalized to any technology with the same value for that variable. While the variable-centered approach is focused on technology features or attributes, it is perhaps more meaningful to approach media technology from an affordance point of view than from an attribute or feature point of view.

Unlike traditional media where audience activity is for most part limited, new media invites interaction and active exploration. Affordances focus on the interaction between media technologies and those who use them, making it a powerful tool for thinking about technologies (Gaver, 1991). Affordances describe the relationship between the properties of the environment and the one’s possibilities for action (Gibson, 1979). This study identified navigability as one of the primary affordances in spatialized new media and through the process of explication, clarified its meaning as well as identified its sub-components. By situating the technological attributes within the context of use, media affordances can offer more meaningful insights, than those gained by focusing on technology features or users alone. An affordance-based implementation of the variable-centered approach allows one to extend findings from a given technology on a specific affordance to any other technology which has a similar value on that affordance.

**Practical Implications**

This study has practical implications for entertainment media that are spatial in nature, ranging from interactive video games to online environments such as SecondLife™. The four-way interaction at the multivariate level indicates that the navigability affordances and narrative transportation taken together have an impact on the four spatial presence dimensions. Practical implications of the three navigability affordances and narrative transportation for design and development of interactive entertainment media, specifically video games and architectural visualization are discussed next.
**Interactive video games & Entertainment Media**

**Steering control**

Significant main effects for steering control underline the importance of locomotion in a video game environment. An extra degree or two in freedom of movement can greatly improve spatial presence in a game environment. Most video game displays are limited to the size of a large flat screen television. In such an environment, many of the spatial cues provided by large screen stereoscopic display are unavailable and therefore spatial cues triggered by movement will acquire even greater significance. User interfaces and input devices with greater degrees of freedom and better maneuverability can dramatically improve the spatial presence experience in the game environment. Given this, the popularity of the Nintendo Wii gaming console with its innovative input remote is not surprising, despite relatively greater realism found in the game environments created by Nintendo’s competitors. Input devices which provide greater steering control can enhance a game player’s self-location, perceptions of motion, action possibilities and perceive the game environment to be more realistic.

**Environmental constraints**

This study did not detect any impact of environmental constraints on spatial presence. While constraints analogous to real world may make their mental representation easier, they may not have a significant impact on spatial presence. This suggests that as long as constraints in game environments are consistent throughout the game environment, even if they are not analogous to real world, will not affect spatial presence negatively.

**Guidance**

Most game environments today have complex spatial configurations, including their own unique guidance features, commonly in the form of “you are here” maps which
constantly update the gamer’s position coordinates in the game world. Findings from this study indicate that while these guidance tools improve spatial understanding, they can have a negative impact on spatial presence by cueing complexity of the spatial organization. By providing an exocentric point of view of the space, they can also reduce the gamer’s feeling of self location in the game environment. One solution to this problem is to implement guidance features such that the gamers activate them only for the time they need assistance with wayfinding. At other times they can be hidden from view.

*Narrative transportation*

Findings related to narrative transportation have interesting implications for game developers. Results indicate that greater narrative transportation, while detrimental to spatial presence, contributes significantly to enjoyment. This suggests the need for a highly nuanced approach to game design with respect to its narrative and careful consideration of the eventual game experience. The complexity of the narrative and the role of the gamer in that narrative must be carefully considered to strike a fine balance between greater enjoyment and greater spatial presence, especially in games where spatial presence is of critical importance.

*Spatial 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 a 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 enhance spatial presence may provide designers an opportunity to ‘inhabit’ the spaces under design and evaluate their experiential aspects.

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. 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. Design tools should have the ability to easily switch from a representational mode to an experiential mode without complicated programming or scripting requirements. Incorporating greater steering control and physicality analogous to real world in design visualization tools will help designers better visualize and experience the spaces they design.

Limitations

The findings from this study should be considered in light of the limitations discussed below, and future studies should strive to overcome them. The two step model of spatial presence posited by Wirth et al. (2007) required the successful formation of a spatial situation model (SSM) as mediating step toward achieving a sense of spatial presence. Unlike text modality or even motion-picture ones, the choice of a large screen immersive VR environment could have potentially resulted in an overabundance of spatial cues, eliminating the need to create and maintain a SSM in the participant’s mind. Secondly, the limited extent
of the interior office environment in our stimulus may have lacked the complexity for better steering control to significantly impact the formation of a SSM. Future studies can examine at what level of complexity of the world, steering control makes a significant impact on SSM. Another important limitation associated with the SSM was that it was conceptualized without taking into account its relationship with other situation models arising out of narrative transportation. The results indicated that despite scoring higher on measured SSM, subjects in the high narrative transportation had lower spatial presence. This could be due to tying up of the cognitive resources in processing and updating other situation models. Thus, by taking into account other situation models pertaining to time, causal relationships and the protagonist, some of the counter-intuitive findings in this study may be better explained in future studies. Inclusion of additional situation models will indicate if the cognitive resources are indeed tied up in processing these models.

Gender has been shown to have a significant impact on spatial abilities and on spatial presence. In the exploratory MANCOVA and ANCOVA models in this study, gender was used a covariate to remove its effect on the spatial presence and thus better explain the impact of the navigability variables and narrative transportation. Since inclusion of gender did not make any significant difference in the model and since the male to female ratio in each experimental cell was not consistent, gender was not included in the analysis. In future studies, where the subject pool is larger, gender should be better controlled through blocking in the experiment design.

Environmental constraint was implemented in the study through collision detection. In the high constraint condition, subjects were prevented from going through solid walls, but in the low constraint condition, they could pass through any solid wall. However, the only available feedback for environmental constraint was through the visual modality. The feedback may have been sufficient to detect the existence of constraints but may not have been qualitatively or quantitatively sufficient to impact the different dimensions of spatial
presence. Future studies can overcome this limitation by adding additional constraints and opportunities to interact with objects in the scene.

A major challenge in spatial presence research is in choosing appropriate measures to capture spatial presence. Given the complexity of the experimental design, the choice of setting and time constraints, spatial presence was measured in this study using post-test questionnaires. Relying on post-test questionnaires alone for measuring spatial presence can fall short, as shown by Slater (2004). Using an arbitrary concept named ‘colorfulness of the experience’, Slater (2004) warns us of the pitfalls of relying solely on questionnaires to measure presence since it offers no indication as to the occurrence of the concept before being primed by the questionnaire. Presence measurement is still a challenge, and two supplementary approaches in addition to the questionnaires are behavioral responses and psychophysiological measures, which future studies can include in addition to questionnaires.

**Directions for future research**

An obvious area for future research is to further explore the role of spatial situation models in spatial presence by overcoming some of the limitations of this study. Future studies should conceptualize situation models better by locating them within the larger context of situation models and examining the relationship between spatial situation models and other dimensions of situation models. This will help to understand better the cognitive process behind the formation of spatial situation models and identify any limitations on cognitive processing when the overall situation models are complex. The highly immersive virtual reality environment used in this study could have undermined the relative importance of spatial situation models in the formation of spatial presence by providing direct visual-spatial cues. Future research can explore the role of spatial situation models in less immersive and less spatialized environments as well as in other modalities. Another area pertaining to spatial situation models which needs further development is to improve the
measurement of spatial situation models. Instead of using retrospective measures such as the ones used in this study, future studies can develop better measures which tap into the evolving nature of spatial situation models using think-aloud protocols or using psychophysiological measures such as EEG which can detect activation in brain areas pertaining to spatial information processing.

This study examined in depth the impact of navigability affordances on spatial presence. Future studies can examine the impact of other variables of the Sundar’s (2008) MAIN model, particularly modality and interactivity, on spatial presence. Similar to this research, future studies can explicate modality and interactivity, identify sub-components of these affordances and examine their impact on spatial presence. Additional research in that direction will provide a comprehensive understanding of how the four key affordances of new media impact spatial presence formation. One potential challenge in such an approach is keeping the number of independent variables at manageable levels. Once all the potential sub-components of these affordances are identified, preliminary experiments can adopt screening designs (fractional factorial designs) to find important components for further experiments. Screening designs keep the complexity of the experiment design manageable by sacrificing some of the higher order interactions between independent variables. Such studies will also provide a comprehensive list of cognitive heuristics that shape both spatial situation models as well as spatial presence.

Like spatial situation models, spatial presence is also a highly dynamic phenomenon and its measurement in real-time is another important area for future research. Psychophysiological measures, behavioral measures and protocol analysis can tap into the real-time dynamics of spatial presence formation. These measures are unobtrusive and have the added advantage that they can eliminate some of the social desirability issues common to questionnaire-based measures. Inclusion of psychophysiological measures can give us a finer understanding of formation of SSM and help distinguish the validity of the heuristics-based approach proposed here. Psychophysiological measures of presence have been more
successful especially where in mediated environments and contexts in which the
physiological responses are highly predictable (for e.g. in stressful environments) as shown
by Meehan et al. (2002). For a person experiencing spatial presence, the primary ego
reference frame should be in the mediated world, which implies that the affordances of the
mediated world should over-ride the affordances of the immediate physical world. This would
imply that he/ she should show behavioral and physiological responses to situations within
the virtual environment. For example, a surprising event within the virtual environment, say a
vehicle moving quickly across the screen at a cross junction without warning or certain
sounds such as that of emergency vehicles, should elicit psychophysiological responses,
particularly orienting responses. Recent studies have shown that navigation or simulation of
movement in virtual environments evoke activity in the parietal brain areas as well as known
to be involved in navigation as well as theta oscillations (EEG activity in the 4-8 Hz. range)
associated with encoding and retrieval of spatial information. Psychophysiological measures
can be used in addition to presence questionnaires building on prior work (Meehan et al.,
2002; Slater et al., 2006). EEG measures can be used as a surrogate for spatial presence
building on prior research. Measures of heart rate variability and skin conductance can also
be used to capture orienting and arousing experiences.

Conclusion

Navigability is a key affordance of virtual environments, designed to help users to
move through spaces and locate themselves in spatial terms. However, little is known about
the mechanism by which navigability affects spatial presence. Intending to reduce this gap in
spatial presence research, this dissertation examined the impact of navigability on spatial
presence. Through an explication process, sub-components of navigability were identified
and their impact on spatial presence explored through a controlled experiment. The study
revealed that one of those components, steering control, significantly enhanced spatial
presence. Contrary to expectation, narrative transportation decreased spatial presence but
increased enjoyment. Findings from the study provided insights into spatial presence mechanisms and highlighted the role of heuristic cues. Boundary conditions were suggested with respect to mental capacity limitations for processing spatial presence cues and the mediating role of spatial situation models. It is important to recognize the importance of spatial presence as a theoretical construct underlying spatialized, interactive media and future studies can further explore the mechanisms underlying its formation as well as impact.
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Appendix – A

Questionnaires

Part – 1 Demographic and Control Measures

Please complete the following questions

1. Age: _______ years

2. Gender: ☐ Male ☐ Female

3. College: __________________________________________________

4. Major: ____________________________________________________

5. Academic standing ☐ Freshman ☐ Sophomore
   ☐ Junior ☐ Senior ☐ Graduate

6. Please estimate the average hours per week during this term that you spent using any computer for course related activities. Please include all your courses in your estimate and consider all course related activities for which a computer was used (for example word processing, computer aided design, multimedia design and presentation, course related e-mail etc).

   This semester, on average I spent ______ hrs per week using a computer on all course related activities.

7. Please estimate the average hours per week during this term that you spent using any computer for any personal or leisure related activities (for example personal e-mail, chat, games, watching movies, online shopping etc).
This semester, on average I spent _______ hrs per week using a computer for personal or leisure related activities.

8. Please estimate the average hours per week during this term that you spent playing video games.
This semester, on average I spent _______ hrs per week playing video games.

9. Please estimate your experience with 3d-modeling with computer aided design software (Form.Z, AutoCAD, SketchUp, 3dStudio Max, etc) in general.
I have _____ years and ______ months experience in 3-dimensional modeling with computer aided design software. (Please enter 0 if you have not used any 3-d modeling software)

10. Please estimate your experience with 2d-graphics software (Photoshop, Illustrator, InDesign, QuarkExpress, etc) in general.
I have _____ years and ______ months experience in using 2 dimensional graphic design software. (Please enter 0 if you have not used any 2-d graphic design software)

11. Please estimate extent of your experience with interactive video games.
I have _____ years and ______ months experience playing interactive video games.
(Please enter 0 if you have not played any video games)

12. Please list your favorite video games. Please leave blank if you do not play video games.
   a. ___________________________
   b. ___________________________
   c. ___________________________
   d. ___________________________
   e. ___________________________
13. Have you ever played any video game based on the Crime Scene Investigation (CSI) television series.

_____ yes
_____ no

14. To what extent have you used joysticks for video games or other computer applications

rarely  0  1  2  3  4  5  6  7  8  9 quite a lot

15. How often do you watch the television series CSI: Crime Scene Investigation

rarely  0  1  2  3  4  5  6  7  8  9 quite a lot
Spatial Imagery Scale assessing preferences for representing and processing schematic images

Instructions for the next set of items on the questionnaire

On a scale from 0 (strongly disagree) to 7 (strongly agree) please indicate the extent to which you agree with the following statements regarding your navigation in the office environment. Please work through each statement at a reasonable pace without dwelling on any specific statement for a long time.

I was very good in 3-D geometry as a student.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

If I were asked to choose between engineering professions and visual arts, I would prefer engineering.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

Architecture interests me more than painting.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I prefer schematic diagrams and sketches when reading a textbook instead of colorful and pictorial illustrations.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

My images are more like schematic representation of things and events rather than detailed pictures.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I can easily imagine and mentally rotate 3-dimensional geometric figures.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree
I normally do not experience many spontaneous vivid images; I use my mental imagery mostly when attempting to solve some problems like the ones in mathematics.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

I can easily sketch a blueprint for a building that I am familiar with.

<table>
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<tr>
<th>Strongly Disagree</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

I am a good Tetris player.

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<th>Strongly Disagree</th>
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<th>3</th>
<th>4</th>
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<th>6</th>
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<th>9</th>
<th>Strongly Agree</th>
</tr>
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</table>

I have excellent abilities in technical graphics.

<table>
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<tr>
<th>Strongly Disagree</th>
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<th>3</th>
<th>4</th>
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<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Strongly Agree</th>
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</table>

In high school, I had less difficulty with geometry than with art.

<table>
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<th>Strongly Disagree</th>
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<th>6</th>
<th>7</th>
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<th>9</th>
<th>Strongly Agree</th>
</tr>
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</table>

When thinking about an abstract concept (e.g. ‘a building’) I imagine an abstract schematic building in my mind or its blueprint rather than a specific concrete building.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

My images are more schematic than colorful and pictorial.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

I find it difficult to imagine how a 3-dimensional geometric figure would exactly look like when rotated.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>0</th>
<th>1</th>
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<th>6</th>
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<th>8</th>
<th>9</th>
<th>Strongly Agree</th>
</tr>
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</table>

My graphic abilities would make a career in architecture relatively easy for me.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>0</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>
Object Imagery Scale assessing preferences for representing and processing vivid images

My images are very colorful and bright.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

When reading fiction, I usually form a clear and detailed mental picture of a scene or room that has been described.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I have a photographic memory

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

When entering a familiar store to get a specific item, I can easily picture the exact location of the target item, the shelf it stands on, how it is arranged and the surrounding articles.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

My images are very vivid and photographic.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

If I were asked to choose between studying architecture and visual arts, I would choose visual arts.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

My mental images of different objects very much resemble the size, shape and color of the actual objects that I have seen.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

When I imagine the face of a friend, I have a perfectly clear and bright image.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I can easily remember a great deal of visual details that someone else might never notice.
For example, I would just automatically take some things in, like what color is a shirt someone wears or what color are his/her shoes.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I enjoy pictures with bright colours and unusual shapes like the ones in modern art.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

Sometimes my images are so vivid and persistent that it is difficult to ignore them.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I can close my eyes and easily picture a scene that I have experienced.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I remember everything visually. I can recount what people wore to a dinner and I can talk about the way they sat and the way they looked probably in more detail than I could discuss what they said.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

My visual images are in my head all the time. They are just right there.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

When I hear a radio announcer or a DJ I've never actually seen, I usually find myself picturing what he or she might look like.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

Santa Barbara Sense of Direction (SBSoD) Scale measuring environmental spatial ability

I am very good at giving directions.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree
I have a poor memory for where I left things.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I am very good at judging distances.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

My “sense of direction” is very good.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I tend to think of my environment in terms of cardinal directions (N, S, E and W).

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I very easily get lost in a new city.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I enjoy reading maps.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I have trouble in understanding directions.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I am very good at reading maps.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I don't remember routes very well when driving as a passenger in a car.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**

I don't enjoy giving directions.

**strongly disagree** 0 1 2 3 4 5 6 7 8 9 **strongly agree**
It is not important to me to know where I am.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I usually let someone else do the navigational planning for long trips.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I can usually remember a new route after I have traveled it only once.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I do not have a very good “mental map” of my environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

Part – 2  Dependent measures, manipulation checks and control measures

General Instructions
On a scale from 0 (strongly disagree) to 9 (strongly agree) please indicate the extent to which you agree with the following statements regarding your experience while navigating the office environment. Please work through each statement at a reasonable pace without dwelling on any specific statement for a long time.

Spatial Presence: Self-location items
I felt like I was actually there in the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I felt as though I was physically present in the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

It seemed as though I actually took part in the action in the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree
**Spatial Presence: Possibilities for action items**

I felt like I could move around among objects in the office environment portrayed.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

The objects portrayed in the office environment gave me the feeling that I could do things with them.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

It seemed to me that I could do whatever I wanted in the office environment portrayed.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

**Spatial Presence: Vection items**

My sense of movement inside the office environment was very compelling.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I could examine the objects in the office environment from multiple viewpoints.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

My sense of movement inside the office seemed very natural.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I felt a compelling sensation of self-motion within the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

**Spatial Presence: Reality Judgment items**

In your opinion, how was the quality of images in the navigation environment?

not at all realistic 0 1 2 3 4 5 6 7 8 9 highly realistic

To what extent did your interactions within the office environment seem natural to you, like in the real world?
not at all natural 0 1 2 3 4 5 6 7 8 9 highly natural

To what extent did the experience seem real to you?

not at all realistic 0 1 2 3 4 5 6 7 8 9 highly realistic

How real did objects portrayed in the office environment seem to you?

not at all realistic 0 1 2 3 4 5 6 7 8 9 highly realistic

To what extent was your experience in the office environment congruent to other experiences in the real world?

not at all congruent 0 1 2 3 4 5 6 7 8 9 highly congruent

Enjoyment

I liked searching for clues in the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I felt good searching for clues in the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

It was entertaining to search the office environment for clues.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I had a good time searching the office environment for clues.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

It was exciting to search the office environment for clues.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree
Spatial Situation Model

I was able to imagine the arrangement of the rooms in the office environment very well.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I had a precise idea of the spatial surroundings in the office environment.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I was able to make a good estimate of the sizes of various rooms in the office environment.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I still have a concrete mental image of the office environment where I carried out the investigation task.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I was able to make a good estimate of how far apart things were from each other in the office environment.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

Attention Allocation

I devoted my whole attention to the office environment.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

My attention was claimed by the office environment.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I dedicated myself completely to the investigation task at hand in the office environment.

- strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

Higher Cognitive Involvement

Much of my thinking had to do with the office environment.
I thoroughly considered all things portrayed in the office environment and what they had to do with one another.

The office environment activated my thinking.

I thought about whether the office environment could be of use to me.

Suspension of Disbelief
I did not concentrate on whether there were any inconsistencies in the office environment that was portrayed.

I did not really pay attention to the existence of errors or inconsistencies in the office environment that was portrayed.

I did not take a critical viewpoint of the office environment that was portrayed.

Manipulation check - Steering Control
How effortlessly could you move forward and backward using the joystick?

How restricted was your sideways movement while using the joystick?
How widely could you turn around (pan) while using the joystick?

**very restricted** 0 1 2 3 4 5 6 7 8 9 **very widely**

How widely could you look up or down the scene using the joystick while looking for clues?

**very restricted** 0 1 2 3 4 5 6 7 8 9 **very widely**

How effortlessly could you steer through the office environment using the joystick?

**with great effort** 0 1 2 3 4 5 6 7 8 9 **very effortlessly**

How effortlessly could you turn tight corners in the office space using the joystick?

**with great effort** 0 1 2 3 4 5 6 7 8 9 **very effortlessly**

**Manipulation check – Environmental Constraints**

How smooth was your movement through the office environment?

**highly constrained** 0 1 2 3 4 5 6 7 8 9 **highly seamless**

To what extent did you feel that walls and other solid objects in the office space obstructed your motion?

**very obstructing** 0 1 2 3 4 5 6 7 8 9 **not at all obstructing**

To what extent did you feel like you could move through solid objects?

**not at all** 0 1 2 3 4 5 6 7 8 9 **to a great extent**

**Manipulation check – Guidance**

To what extent did you feel that the tablet PC dashboard was useful in guiding you through the office space.
To what extent did you pay attention to the tablet PC dashboard while moving through the office space?

To what extent did you reference the tablet PC dashboard to find your way through the office space?

To what extent did the tablet PC dashboard give you an idea about the organization of the office space?

To what extent did the tablet PC dashboard give you an idea about your location within the office space?

To what extent did the tablet PC dashboard give you an idea about location of clues to the case?

**Manipulation check – Narrative transportation**

*Please recollect the instruction given earlier in the study.* Please indicate whether you were ...................... (complete by checking only one choice from below)

- asked to imagine yourself in the role of a CSI investigating a case.
- asked to evaluate the quality of visual quality of the graphics for the CSI game.
- do not remember any instructions
I felt myself to be more in a critical mode, evaluating the overall visual quality during the presentation of screenshots and while in the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I felt myself to be more in a CSI role player mode assigned to investigate the crime during the presentation of screenshots and while in the office environment.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

I felt myself to be _____________ during the presentation of screenshots and while in the office environment.

a passive observer 0 1 2 3 4 5 6 7 8 9 in the midst of action

I could easily relate to the role of a crime scene investigator.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

While reading the briefing of the murder case in the screen shots, I found my mind wandering

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

While reading the briefing of the case in the screen shots, I was mentally involved in sequence of events

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree

After the briefing of the murder case in the screen shots, I wanted to learn how the crime occurred.

strongly disagree 0 1 2 3 4 5 6 7 8 9 strongly agree
Appendix - B
Experiment Protocol & Script for verbal instructions

The day before the experiment.
1. Send e-mail with information on
   a. Time slot signed up for
   b. Links to the directions to IEL & pre-lab questionnaire

Before the subjects arrive at Immersive Environments lab
1. Log on to the console machine
2. Load the appropriate VRML file corresponding to the experimental conditions
   a. Residence model (for training) – Set full screen
   b. Stimulus
3. Set the views to the starting camera position
4. Have joystick and glasses ready. Test whether joystick is working. Look for signs of weak battery for the joystick.
5. Load the appropriate power point file based on the level of narrative variable
6. Have 2 copies of signed informed consent forms ready
Part -1 Welcome & Overall instructions

On arrival of participants for a given session

1. Greet the subjects, ask to sign in and give an overview of the study.

   **Script:** Thanks for coming. Really appreciate your participation and what we will be doing is to explore how the CSI Game will look like in a VR environment.

[For high narrative] - Your part in the research is to role-play a CSI agent looking for clues in a crime scene. So try to keep this in the back of your mind for every task involved in the study. Use your imagination. Think about the setting, about how you might feel in the situation as a real-world crime scene investigator. Immerse yourself the action of the story. Pay attention to all incidents described in the plot. These aspects are critical to the younger audience towards whom the game is targeted. But before we get into the CSI part, we will get some practice on using the joystick.

[For low narrative] - Your part in the research is to evaluate the overall visual quality of the CSI game’s opening screens and usability of the game environment. Use your evaluative skills. Think about the overall quality of the presentation. Pay more attention to the overall composition, font quality and size, quality of visuals etc. These aspects are critical to the younger audience towards whom the game is targeted. Always maintain an evaluative or critical frame of mind. But before we get to that part, we will get some practice on using the joystick.

   **Script:** Once you are comfortable, with the joystick you will go through a presentation of the game context and then navigate the game environment in VR. You will conclude by completing a questionnaire and a related task. But before we can begin, I need your signature on the informed consent form. [Walk participants through the consent form]. Please sign both copies and retain one for your records.

2. Get signature on consent form. Hand one signed copy back to the subject for their records.

3. Collect the demographic portion survey. Mark serial number and experimental condition in the space provided for the same at the top right corner of the forms.

4. **Script:** I will show you how to use this particular joystick. You can practice using the joystick on the residence displayed on screen. [Demonstrate while instructing].

127
**Low steering control:**
The use of joystick is very simple and straightforward. To move forward move the stick forward and to move backward bring it backwards. To turn, move the joystick to the right or left. Other types of actions using the joystick such as twisting or use of buttons are disabled will have no effect on your movement. Since the distances to be covered are usually small, please use delicate movements of the joystick. This is important for turning tight corners and to ensure that you do not overshoot your desired target. Settle for a pace that is comfortable for you.

**High steering control:**
The use of joystick is very simple and straightforward. To move forward move the stick forward and to move backward bring it backwards. To turn, move the joystick to the right or left. Some times it is useful to slide to one side or another rather than turning, such as when you have to make slight adjustment to the path. To slide, press the thumb button while moving the joystick to the side that you want to slide to. If you desire to look up or down, you need to use the trigger. To look down, pull the trigger and move the joystick forward. To look up, pull the trigger and move the joystick backward. Other types of actions using the joystick such as twisting or use of buttons other than the trigger and the thumb are disabled will have no effect on your movement. Since the distances to be covered are usually small, please use delicate movements of the joystick. This is important for turning tight corners and to ensure that you do not overshoot your desired target. Settle for a pace that is comfortable for you.

5. **Script for collision feature:**

**High collision condition:**
The advantage of this environment is such that it mimics real world settings. For example, you cannot pass through solid objects. When you come to a solid object you cannot pass through it and will have to go around it.

**Low collision condition:**
The advantage of this environment is such that it can overcome real world limitations. For example, here you can pass through solid objects. When you come to a solid object you can pass through it and will have to decide if you want to pass through it or go around it.
6. Allow the subjects to practice using the joystick until they are comfortable navigating the maze environment without help. Answer any questions that may arise regarding the use of the joystick or procedures in the experiment.

Part -3 Narrative Presentation

1. Make Narrative Presentation full screen on IEL display

2. Instruct the subject on their role during the narrative presentation based on the narrative condition

**High Narrative:** Now that you are comfortable with using the joystick, I will present you with the opening screens being developed for the game. After this you will be presented with the game environment. Imagine that you are a CSI™ agent in Grissom’s unit and you are about to be briefed by Grissom on a case. While viewing Grissom’s briefing in the presentation, use your imagination. Think about the setting, about how you might feel in the situation as a real-world crime scene investigator. Immerse yourself in the action of the story. Pay attention to all incidents described by Grissom. It is important to pay close attention to instructions following the briefing, which are concerned with certain display tools available for your use in the game environment. Once you have completed going through the opening screens of the game, you will be automatically taken to the game environment where you will continue to assume the role of a CSI™ agent and try to solve the crime. When you are at the crime scene, examine each nook and corner of the office thoroughly for any clues. When you find a clue, make a mental note of it in your mind and keep looking for further clues. You will be given 10 minutes to explore the crime scene and try to solve the case after which you can complete the second questionnaire.

**Low Narrative condition:** Now that you are comfortable with using the joystick, I will present you with the opening screens being developed for the game. After this you will be presented with the game environment. The new CSI™ game is targeted at much younger audience and as such the needs to be evaluated for its visual quality of the opening screens as well as for the eventual game environment. In the given handout there are screenshots from the opening screens. Against each screen is a set of evaluative criteria. Please mark scores out of 10 for each item for a given screenshot. Once you have completed the evaluation, the instructions displayed on screen are concerned with certain display tools available for use in the game environment. It is important to pay close attention to these instructions. Once you have completed going through the opening screens of the game, you will be automatically taken to the game environment. The gamers are required to find clues to solve the crime described in the opening screens of the game. It is important
to evaluate the overall quality of the CSI™ game environment as you explore the game are looking for clues. Even factors like the number of interior doors and if they are wide enough, number of windows and if they offer views of the exterior, if the interior color schemes match and if the rooms are adequately and appropriately furnished are all important. So, while you are searching for clues, keep a rough mental note of the number of interior doors and number of narrow ones, number of windows and the ones which don’t provide a good view, overall quality of the color scheme and the furniture arrangement. When you find a clue, make a mental note of it and keep looking for further clues. You will be given 10 minutes to explore the game environment for clues after which you can complete the second questionnaire.

**Note:** Subjects in low narrative will be given a handout of the screen slides with 7-point scales (from poor to excellent) for

- Overall color scheme,
- Font quality and size
- Overall quality of layout
- Verbosity of the screen content

**Part -4 Guidance Instructions**

The guidance instruction slides will follow the Narrative presentation. They will have the same look and feel to maintain continuity. To ensure that subjects in all conditions pay attention to the guidance, the evaluative task for the low narrative condition will end before the guidance instructions.

**High guidance**

Slides will instruct to pay attention to the tablet PC dashboard at all times to

- keep track of their location by keeping an eye on the red circle
- get alert in the form of a red square around the “lens” icon for presence of clues to the case

**Low guidance condition**

Slides will instruct to pay attention to the tablet PC dashboard at all times

- Stay alert for the red square around the “lens” icon for presence of clues to the case
Part -5 CSI Navigation task.
Once the subject has completed the Narrative and instruction slides, make the office model full screen and allow the subject 10 minutes to navigate the office environment in search of clues.

Part -6 Second part of the Questionnaire

After the navigation task is completed
1. On completion administer the remaining part of the questionnaire.
2. Brief the subject on the puzzle.
   **Script:** Each picture shown here pertains to one room/area in the office environment. Please arrange them such that any given room is bordered by pictures of the rooms adjacent to it.
3. On completion thank the subjects for their participation; clarify any further questions regarding the experimental procedures, data analysis or use of data.

Part -7 Post Experiment session
1. File the Informed Consent forms in the folder assigned for the same.
2. Mark serial number and date on the questionnaires used in the experimental session and file them in the folder assigned for the same.
3. Lock up the folders in filing cabinet in the experimenter’s office
4. Check sufficiency of consent forms, scenario assessment forms & questionnaire for next session / next day.
Appendix - C

Opening Screens for High Narrative Transportation

Screenshot 01

Screenshot 02

Screenshot 03

Screenshot 04

Screenshot 05

Screenshot 06
Opening Screens for High Narrative Transportation

(Continued)

**Victim Profile**
- **Name**: Sam 'Ace' Rothstein
- **Age**: 63
- **Profession**: Real Estate Developer
- Known past crime record, associated with the mob
- Known to have a number of enemies

**Case file - key points**
- Body discovered in a dumpster adjacent to the office tower
- 9-1-1 call by a janitor in nearby tower.
- Crime is suspected to have happened in Rothstein's office
- Rothstein's secretary saw Rothstein start as he was meeting a potential client after office hours.

**Screenshot 07**

**Screenshot 08**

**It is important for you to understand thoroughly the location and contents of various rooms in Rothstein's office.**

**As a CSI, you may have to recreate it for analysis or in court.**

**Also, go through every room in the office in search of clues. I can never stress enough the importance of being thorough!!!**

**Screenshot 09**

**Screenshot 10**
Opening Screens for Low Narrative Transportation

Screenshot 01

Screenshot 02

Screenshot 03

Screenshot 04

Screenshot 05

Screenshot 06
Opening Screens for Low Narrative Transportation

(Continued)
Guidance Manipulation in Opening Screens

Tablet PC Dashboard for Low Guidance

Tablet PC Dashboard for High Guidance

Screenshot 11

Further Instructions
Reload game
Credits
Quit

Screenshot 11

Further Instructions
Reload game
Credits
Quit

Screenshot 12

When you are near a clue, the lens icon will be highlighted by a red box to alert you.

Your location within the office will be marked by the red circle and will be automatically updated as you move through the space.

Be sure to go through every room in Rollstein’s office for potential clues.

Screenshot 12

What the gamer is near a clue, the lens icon will be highlighted by a red box to alert the gamer.

Gamers have to go through every room in Rollstein’s office for potential clues.

Screenshot 13

Navigation Training
Proceed to Crime Scene
Reload game
Credits
Quit

Screenshot 13

Navigation Training
Proceed to Crime Scene
Reload game
Credits
Quit
Appendix - D

Layout of the Office Environment Virtual Reality Model
Appendix - D

(Continued)

Screenshots of the Office Environment Virtual Reality Model

Elevator Lobby

View from entrance

Reception, View towards waiting area

View towards reception
Appendix - D

(Continued)

Screenshots of the Office Environment Virtual Reality Model

View from waiting area

View of hallway and reception

View of meeting room

View of meeting room
Appendix - D
(Continued)

Screenshots of the Office Environment Virtual Reality Model

View of executive office

View of executive office

View of executive office with clues - strewn files and gun on table

View of gun on the table and clue alert on the dashboard
Appendix - D

(Continued)

Screenshots of the Office Environment Virtual Reality Model

View of board room

View of board room

Clues in the board room - shoes on the floor and bullet casings on table

Clue on the hallway floor - second shoe
Curriculum Vitae

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Education

• Ph.D. in Mass Communications, graduate minor in Applied Statistics
  o The Pennsylvania State University, University Park, PA, December 2008
• M.S. in Architecture
  o The Pennsylvania State University, University Park, PA, May 2004
• B.Arch in Architecture
  o University of Kerala, Trivandrum, India, February 1999

Research & Teaching Interests

• Psychological effects of new media,
• Architectural visualization and design communication
• Role of digital tools in design process and their impact on decision making process
• Psychological aspects of human-computer interaction

Teaching Experience

Instructor, Penn State University
• Arch 281 Introduction to Computer Applications in Architecture, Fall 2005
• Arch 481 Digital Design Media, Spring 2005, 2006 [Co-instructor]

Instructor, National Institute of Technology, Calicut, India
• Professional Practice, Spring 2000
• Architecture Design 1: Introductory Design Studio, Spring 2000 [co-instructor]
• Architecture Design 2: Intermediate Design Studio, Spring 2000 [co-instructor]

Conference Papers and Proceedings Publications [recent]


