'BEING IN' A VIRTUAL ENVIRONMENT: THE RELATIONSHIPE BETWEEN THE EXPERIENCE OF PRESENCE AND SPATIAL ABILITIES

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ABSTRACT

Current theories within the discipline of psychology suggest that a number of factors influence the experience of presence in virtual environments (VEs). Such factors include, among other things, the quality and degree of sensory stimulation offered by the VE, the degree of realism of the material presented to the user, personal interests of the user, and characteristics of the user such as willingness to suspend disbelief and spatial ability. Spatial ability is hypothesized to influence the degree of presence experienced in a VE because spatial ability is related to the construction of spatial situational models of VEs (Vorderer et al, 2003; 2004). It is also related to users' ability to navigate the VE. The purpose of the present study was to examine the relationship between the sense of presence experienced in VEs, users' spatial abilities, and performance on a virtual maze task. It was hypothesized that males would outperform females on mental rotation tasks, and therefore also feel more present in the VE than females. In addition, increased mental rotation ability was hypothesized to improve performance on the virtual maze task. Fifty participants (28 female) completed several tasks used to assess spatial ability, experience of presence, and performance in a VE consisting of a first-person perspective (FPP) virtual maze environment. Spatial abilities were assessed using a redrawn version of the Vandenberg and Kuse Mental Rotation Test (MRT-A), the Object-Location Memory test (Silverman & Eals, 1992), and by asking participants about their use of mental maps. The results provided some support for the hypothesis that the experience of presence in VEs, and users' performance in VEs, is related to the spatial ability of the user. A significant gender difference on the mental rotation task and on the use of mental maps to aid navigation was observed however, males did not feel significantly more present in the VE than females in the present study. Nevertheless, males performed somewhat better than females on the virtual maze task. These findings are discussed in light of participants' previous experience with playing digital games, and recommendations for future research are provided.

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TABLE OF CONTENTS

APPENDIXES

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Virtual environments (VEs) are an increasingly popular topic of study within academic disciplines such as game studies, computer software development, human centred informatics (HCI), philosophy, psychology, and educational studies. The term 'virtual' is often associated with something that does not physically exist as such, but is made by software technology to appear to do so (Steuer, 1992). The most common examples of such VEs are Virtual Reality (VR) simulators. VR simulators involve the stimulation of a large number of sensory modalities including vision, sound, touch, and proprioceptive sensory channels. They include a 360 degree enclosed 3D environment provided through a head-mounted display, wired gloves, and position trackers. Sherman and Craig (2003) define virtual reality as "a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation" (p.13).

However, the term *virtual environment* also refers to a *virtual space* that can only be experienced as a result of the involvement of mental processes (Biocca, 1997). A VE inhabits dimensions of height, depth, and width that are perceived by the individual interacting with that VE. Thus, it can be considered to be a specific structure not physically existing as such, but made by mental processes to appear to do so. The experience of feeling present within a VE is therefore dependent upon the interaction between the medium and human mental processes. The medium provides direct perceptual stimuli that, in the combination with mental process, are perceived as a (virtual) space. Examples of media types considered to facilitate user interaction with a VE, other than VE simulators, include digital games, movies, and books.

Perceiving virtual space involves the operation of mental processes similar to the way we perceive our everyday physical surroundings (Biocca, 1997). When playing digital games a prerequisite for successful movement in the virtual game environment is that users obtain knowledge about and get a sense of the virtual space they are acting within. When watching TV or movies at the cinema, the viewer applies mental processes to perceive the environment presented on the screen as a three-dimensional space. When reading books we imagine the (virtual) space in which the characters of the book are interacting. A term commonly used to describe user experience with different media is *immersion.* The Oxford English Dictionary (2000) defines immersion as "absorption in some condition, action, interest etc." (p.684). Other terms commonly used to describe the immersive experience include engagement, engrossment, absorption, and even addiction.

The concept of immersion has a long history of discussion within the traditions of visual art, or visual representation. During the Middle Ages, the idea of visual art was to create a painting that did not inhabit three-dimensional dimensions in itself, but that this three-dimensional space would be created within the viewers own imagination. The 'vanishing point' of the painting during this era was therefore located within the viewer, in his or her imagination (McLuhan & Parker, 1968). It was the idea itself, or what the painting represented, that was important, and the viewer was expected to use his or her imagination to place him-or herself within the context of the represented image. During the Renaissance however, artists started experimenting with creating the representation of a visual three-dimensional space within the painting itself. The revolutionary idea of placing the 'vanishing point' of the image representation within the painting rather than within the viewer created the illusion of an extended space between the painting and the viewer. It was a space created by the medium and the viewer's imagination (i.e., a virtual space). Grau (2003) gives a comprehensive account of immersion in 360 degree works of art through the ages, from villa paintings in Pompeii to nineteen century panoramas to contemporary VEs:

> Immersion arises when the artwork and technical apparatus, the message and medium of perception, converge into an inseparable whole. At this point of calculated "totalisation", the artwork which is perceived as autonomous aesthetic object, can disappear as such for a limited period of time: this is the point where being conscious of the illusion turns into unconsciousness of it. As a general rule, one can say that the principle of immersion is used to withdraw the apparatus of the medium of illusion from the perception of the observers to maximize the intensity of the message being transported. The medium becomes invisible (Grau, 2003, p. 249).

This conception of immersion places great importance upon the spatial properties of the environment in question. The most salient characteristic of immersion is the sense of inhabiting a represented space. Within the current research literature, especially in psychology, this phenomenological experience of feeling present in the represented space has been labelled 'presence' (e.g., Lombard & Ditton, 1997; Sheridan, 1992; Slater & Steed, 2000; Slater & Wilbur, 1997; Vorderer et al., 2003). Thus, *presence* refers to the experience of *being in* a virtual, or mediated, space. Psychological research has focused on both technological and psychological factors to understand this concept, including visual display characteristics (e.g., graphics quality, camera techniques), level of realism of the VE, illusion of non-mediation, level of interactivity (e.g., between the user and the VE), willingness to suspend disbelief, knowledge of and experience with the medium, and the spatial ability of the user. Although spatial ability has been recognized to be an important factor in the experience of presence in VEs, most research has focused the relationship between presence and navigation rather than its relationship to specific spatial abilities.

Following these trends within psychological research on presence, the overall aim of the present thesis is to investigate the relationship between the sense of presence experienced in virtual environments (VEs) and users' spatial abilities. More specifically, the relationship between mental rotation ability, object-location ability, gender, presence in a VE, and performance in a virtual maze task was assessed. Thus, two tests, the Vandenberg and Kuse Mental Rotation Test (MRT-A) and the Object-location Memory Test (OLMT), were used. In addition, a virtual maze was developed and a presence measure, the MEC Spatial Presence Questionnaire (MEC-SPQ), was used to evaluate users' experience of presence in that VE. This thesis also aims to show how mental rotation ability in particular, influences the experience of presence in first-person-perspective (FPP)[1] VEs. Both mental rotation ability and the construction of a spatial-situational model of the VE (i.e., which is considered necessary for presence to occur according to the MEC model of presence) require an ability to hold complex spatial information in working memory (Cornoldi & Vecchi, 2003; Vorderer et al., 2003). Similarly, the use of mental maps puts demands on working memory capacity (Cornoldi & Vecchi, 2003). Thus, participants' mental rotation ability was investigated in

[1] See chapter 3, section 3.3.2 for a more thorough definition of this term.

relation to users' sense of presence and use of mental maps. Further, this thesis aims to show how a FPP VE puts increased demands on a user's ability to hold complex spatial information in working memory as compared to a third-person-perspective (TPP) VE. In addition, it aims to show how the use of mental maps may be particularly important when navigating a VE from a FPP as opposed to a TPP. Thus, both mental rotation ability and the use of mental maps are investigated in relation to performance in a FPP VEs.

To summarize, the relationship between presence, mental rotation ability, the use of mental maps to aid navigation, and navigation in a FPP VE is the focus of this thesis. Chapter 1 of provides an overview of the project's research aims, chapter descriptions and a description of different types of VEs (see above). Chapter 2 examines a variety of theoretical perspectives of presence. Various aspects of several different positions on presence are combined to provide a working definition that will be used throughout this work. Chapter 3 leads on from the theoretical discussion of presence to examining various measures of presence, including both subjective and objective measures of presence. One measure, the MEC-Spatial Presence Questionnaire (MEC-SPQ), is selected for use in this project based on its comprehensive theoretical model which fits well with the working definition of presence used throughout this thesis. Hence, discussion of the MEC-SPQ is the primary focus of this chapter. Chapter 4 examines the second key variable of interest for this thesis: namely spatial ability. The critical discussion of spatial ability reveals that spatial ability can be conceptualized as consisting of a number of underlying sub-factors which are affected by general cognitive factors such as attention and processing speed. In addition, these factors influence navigation and way-finding, and strategies used to complete navigational tasks. Gender differences in some of these spatial abilities have been observed (and are also investigated in the present study), and the influence of specific spatial abilities on navigation in VEs is discussed. Chapter 5 and 6 describe the empirical research component of this thesis. The present study applies a quasi-experimental design. As mentioned above, spatial ability is measured by the MRT-A and the OLMT, and participants' experience of presence in a VE is measured by the MEC-SPQ after interaction with a virtual maze. Performance on the virtual maze task is measured in terms of time to complete the virtual maze and the number of errors made while navigating it. Chapter 6 includes a discussion of the results and conclusion of the present study, as well as recommendations for future research.

1 PRESENCE

The study of presence, or the feeling of 'being in', a virtual environment (VE) is a growing topic of study within a number of scientifically-oriented disciplines. One of the main contributors to this research is the field of psychology. In accordance with researchers from other scientific approaches, psychology based research of presence base itself on a rationalist and Cartesian view of reality (Flach & Holden, 1998). This view emphasizes the separation of the 'subject' from the 'object' and argues that objective knowledge about phenomena in the world can be obtained. Researchers following this perspective tend to consider the medium a source of objective information about presence and the individual a source of subjective information about presence, and information derived from both medium and individual are used to arrive at definitions of the presence phenomenon. However, more recently a number of other theoretical approaches to understanding presence in VEs have emerged in the presence literature. First, the ecological view opposes the Cartesian view of reality and offers new understandings of presence based on the interdependent relationship between individuals and their environment (Zahoric & Jenison, 1998). Second, the estimation theory of presence attempts to bridge rationalist and ecological views into one unified theory of presence (Sheridan, 1999). Third, the embodied cognitive framework builds on the ideas of both cognitive psychology and the ecological view by assigning the body a determining role in the experience of presence in an environment (Schubert, Friedmann, & Regenbrecht, 1999). Finally, the socio-cultural view highlights the way our social and cultural context mediate the presence experience (Mantovani & Riva, 1999). These different theoretical views of reality and human experience naturally lead to different understandings of presence. This chapter will take a closer look at different definitions of presence derived from these theories and their individual influence on the study of presence.

1.1 The Traditional View

The study of presence within psychological research follows from the rationalist tradition of ontological[2] inquiry (Zahoric & Jenison, 1998). The rationalist tradition encompasses the Cartesian separation of the 'object' from the 'subject' and this assumption is common in a number of scientific disciplines, such as the physical sciences, cognitive sciences, and engineering, among others (Flach & Holden, 1998). Such disciplines hold that it is possible to arrive at an objective truth about phenomena in the world. Rationalism is often referred to as the Traditional Scientific Approach (Zahoric & Jenison, 1998) and intellectuals following Descartes, such as Spinoza and Leibniz, have contributed to the development of this perspective. The most visible trace of this position within psychological studies of presence in VEs is the dualistic separation of the real[3] from the virtual[4]. In presence research of this kind, knowledge about the real world is compared to knowledge about the VE and presence is understood as arising from a combination of the user's characteristics on the one side, and the characteristics of the medium on the other (e.g., IJsselsteijn & Riva, 2003; Lombard & Ditton, 1997; Sheridan, 1992; Slater & Steed, 2000).

The rationalist framework is identified by a problem-solving approach to research in which rules and logic are applied to arrive at conclusions about the world. Zahoric and Jenison (1998) use this framework to discuss rationalistic thinking within cognitive and perceptual psychology, and the information processing approach that underlie these two disciplines. They argue that mental representations are what characterize the topic of investigation in these fields of study and that the 'objects' of importance therefore are the mental representations themselves. This focus on mental properties moves the object of study from the realm of the physical to the realm of the mental, implying that objective knowledge from

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[2] Ontology refers to theories of, or the study of, being and existence (Oxford English Dictionary).

[3] 'Real' refers to our immediate *physical* environment that we inhabit and interact with at every moment of our everyday life. The two terms 'real' and 'physical' will therefore be used interchangeably in this thesis to refer to our real/physical surroundings/world. The 'real' is experienced through human processing.

[4] 'Virtual' refers to that which exists outside of our everyday physical surroundings, or outside the 'real'. The discussion of virtual space provided in Chapter 1 indicates that the 'virtual' is created by both human (e.g., the imagination) and technological devices (e.g., computer graphics, books, paintings). However, the 'virtual' cannot be experienced without human input. On the other hand, it is possible to argue that the 'virtual' can be experienced in the absent of technological input, such as in the case of daydreaming (i.e., the imagined space is what is considered a virtual space).

both physical and mental domains can be obtained. For the rationalist; "perceptions (that which make up an internal phenomenal world) are veridical if they match the state of affairs in the real objective world" (Zahoric & Jenison, 1998, p. 86). Consequently, this view emphasizes the investigation of both the mental properties of the individual and the physical[5] properties of the medium when studying VEs and users' experience of presence in VEs. This also indicates that the experience of (virtual) presence can be compared to the mental and physical domains of the experience of presence in the real world. The development of both 'objective' and 'subjective' tests to measure presence illustrate some of these underlying beliefs, as well as the interest in such topics as attention, memory, imagery, and spatial ability. Next is a summary of the main definitions of presence offered within this rationalist, or traditional, paradigm.

1.1.1 Presence as 'Being In' a Virtual Environment

Steuer (1992), in his article *Defining virtual reality: Dimensions determining telepresence,* suggests that presence can be defined as "the sense of being in an environment" (p. 6). Further, he suggests that the term *telepresence* can be used to describe "the experience of presence in an environment by means of a communication medium" (p. 6). Thus, for Steuer, the term presence is used to refer to the experience of being in our natural, physical surroundings (i.e., the real world) while telepresence is best used to refer to the experience of being in a technology-mediated, non-physical, environment (i.e., a virtual world). The term telepresence was first used in 1980 by Marvin Minsky (cited in Steuer, 1992) to describe the experience of manipulating equipment located in a remote physical location. Thus, this notion of telepresence refers to the experience of presence in a remote physical location at the same time as one is strongly anchored (both physically and mentally) in one's immediate physical location. In contrast, when interacting with such media as VR simulators, movies, and books users may experience a feeling of being present in a non-physical (i.e., virtual) environment. While the former (i.e., telepresence) involves actual consequences in the

[5] The term *physical* here also includes the perceivable qualities that the actual technological architecture of the medium produce (e.g., such as ground, building, moving objects etc.).

physical world the latter does not. However, as both conditions involve an experience of presence that can be considered different from feeling present in our everyday physical world, some further clarification of these terms is needed. In the first issue of the journal *Presence: Teleopertors and Virtual Environments,* Sheridan (1992) suggests telepresence should be used to refer to the experience associated with teleoperation systems only, and (virtual) presence to the experience of being in a VE. In this thesis, I will take up this distinction made by Sheridan and discuss presence, rather than telepresence, as the experience of being in a VE.

There is currently a general consensus among presence researchers that the term *presence* refers to a "sense of being in an environment" where, for the purpose of studying presence in *virtual* environments, that environment is a mediated one. However, much disagreement exists as to how this "sense of being there" should be more specifically defined. An important initial distinction is often made between *presence* and *immersion.* As previously mentioned, the term immersion commonly refers to absorption in some condition or interest (Oxford English Dictionary, 2000). However, as for example within the game industry, this term is also used to refer to the experience of *feeling present in* a represented environment. Thus, the terms immersion and presence at times seem to refer to the same phenomenon. A number of researchers have attempted to clarify this issue.

Some researchers view presence as the outcome of immersion in VEs (e.g., Schubert, Friedmann, & Regenbrecht, 1999, 2001; Slater & Steed, 2000; Slater & Usoh, 1993; Slater & Wilbur, 1997). For example, Slater and Wilbur (1997) define immersion as "a description of technology" (p. 606). In their view, immersion depends on "the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the sense of a human participant" (p. 606). In this case, immersion refers to the objective, technological characteristics of the medium rather than the subjective experience of feeling present in an environment. Thus, this view is radically different from the definition of immersion provided by the Oxford English Dictionary and its deployment in non-academic contexts. To describe the phenomenological experience of being in an environment, Slater and Wilbur adopt the term 'presence'. They define presence as "a state of consciousness, the (psychological) sense of being in the virtual environment" (p. 607).

Witmer and Singer (1998) disagree with the objectification of immersion proposed by Slater and Wilbur (1997). Witmer and Singer (1998) suggest that although immersion is affected by the technology of the medium, the experience of being immersed in a VE is ultimately of a subjective nature and cannot be reduced to the characteristics of the medium: "Immersion is a *psychological state* characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" (italics added, p. 227). Witmer and Singer (1998) agree with the definition of presence offered by Slater and Wilbur (1997), but also offer some further specification of the term: "Presence is defined as the subjective experience of being in one place or environment, *even when one is physically situated in another*" (italics added, p. 225). Further, these authors suggest that a third psychological state, namely that of *involvement*, is necessary for presence to occur. They define involvement as "a psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related activities or events" (p. 227). Involvement, they argue, is influenced by selective attention. That is, the individual focuses on information from the VE that is meaningful and that has particular interest to the individual.

The author of the present thesis disagrees with Slater and Wilbur's (1997) objectification of immersion as this usage of the term removes it from its original meaning and may make it unrecognisable to the reader. Further, Witmer and Singer's (1998) use of the words "enveloped by" and "included in" can be somewhat misleading when different types of VEs are considered. An example of playing Tetris can help explain this claim. A user may get immersed in a game of Tetris[6] by becoming absorbed in the activity and attending to the stimuli arriving from the medium. However, it is unlikely that the user will feel present within the Tetris game as the game does not provide an "inhabitable" virtual space. Rather, immersion in this case can be viewed as involving the capitalization of the user's attentional

[6] In the game Tetris the player is given a sequence of tetromino pieces and must pack them into a rectangular gameboard initially occupied by a given configuration of filled squares; any completely filled row of the gameboard is cleared and all pieces above it drop by one row.

resources. Thus, this thesis will use the term immersion to refer to the experience of being absorbed in a VE through the capitalization of the user' attentional resources, while presence will be used to refer to the specific experience of *being in* a VE.

Authors such as Witmer and Singer (1998), Slater, Usoh, and Steed (1994), Steuer (1992), and Sheridan (1992) note that presence indicates a form of 'transportation' from one environment to the other; from the environment that one is physically situated in to that of the VE. Heeter (1992) discusses three aspects of presence as transportation; personal, social, and environmental presence. Personal presence occurs as a result of a sense of being present within a set of virtual surroundings in a similar way to how we experience being present in the physical world. Environmental presence is experienced when individuals perceive the VE reacting to them as if they actually inhabited that environment. Social presence arises as a result of the existence of other entities within the VE that react to the person as if they shared the same social environment. The concept of presence as transportation raises the question of whether a person can feel present in both her immediate physical environment and the VE at the same time (which seems to be the case in telepresence). Although presence in VEs is experienced as a flowing continuous phenomenon, some authors argue that one can only feel present in either the physical world or the VE at any one time (Biocca 1997; Lombard 2000, cited in Van der Straaten, 2000). Lombard (2000, cited in Van der Straaten, 2000) provides two hypotheses to explain the seemingly continuous nature of presence:

> Presence occurs in an "instant by instant" manner. Although it appears that presence is a continuous rather than a dichotomous variable, it has not been determined whether 1) presence can exist in varying degrees at each instant (as it seems) or 2) our sense that presence is continuous is the result of the cumulative effect of instants, which may be as short as milliseconds, in which presence either does or does not exist (2000, cited in Straaten, 2000, p. 1-6).

These hypotheses can be illustrated by an example from the game Counter Strike. Counter Strike is a first-person shooter computer game that involves two teams; one terrorist team, and one counter terrorist team. The aim of the game is to defeat the opposite team. This can be achieved in three ways: 1) by killing all members of the opposite team, 2) by planting and setting off a bomb (i.e., if you're playing a terrorist), or 3) by disarming the bomb (i.e., if you're playing a counter terrorist). There are usually two areas where the bomb can be planted. The following is an example to illustrate Lombard's hypotheses: The change in intensity of action experienced in Counter-Strike, from the moment the person starts running towards the target area, to being in the middle of a shoot-out, may draw the user's attention *towards* the VE and increase the sense of presence experienced in the VE. In contrast, suddenly realising that one's dinner is getting burnt in the over (in the real world) may draw the user's attention away from the VE to aspects of his or her physical environment. Similarly, a time lag within the game or the sound of the phone calling in the user's physical environment may, at any point during the VE interaction, also draw the user's attention *away* from acting in the VE to the objective features of the game technology or the person's physical surroundings. This may lead to instances during the VE interaction when the user experiences being more present in the physical world than in the VE. However, due to the speed by which these "breaks" in presence occur this moving "in and out" of the VE is experienced in a continuous fashion. Both hypotheses proposed by Lombard imply that there exists some kind of immersive threshold that elicits a shift in location of the user's experience of presence from the physical world to the VE and vice versa. Vorderer et al.'s (2003) spatial situational model of (spatial) presence[7] suggests that the experience of presence in VEs involves, among other things, the unconscious or conscious decision of the user to consider the VE as her primary egocentric frame of reference (PEFR). The egocentric frame of reference refers to the frame of reference that locates the user and his or her body[8] within a particular environment. When interacting with a VE, competing egocentric frames of reference will be evident, that which is located in the VE and that which is located in the physical world. When the user has 'chosen' the VE as her PEFR and this frame of reference is stabilized, the user feels present in the VE rather than her physical surroundings, and vice versa. Part of this process is the inhibiting of distracting stimuli arriving from the physical environment. Similarly to Lombard (2000, cited in Straaten, 2000), Vorderer et al.'s (2003) theory indicates the existence of an immersive threshold resulting in a shift of consciousness

[7] Vorderer et al.'s conceptualisation of presence will be described in greater detail in the next chapter of this thesis.
[8] Vorderer et al.'s emphasis on the location of the 'body' draws on Gibson's ecological theory of perception and 'affordances'. When feeling present in a VE the user experiences the location of their (virtual) body as being situated in the VE due to the possibilities for action, or affordances, offered by the VE. I will talk more about Gibson's theory of affordances later in this chapter.

between feeling present in the physical world to feeling present in the VE[9]. However, when considering the VE experience over an extended period of time, the fact that users' level of presence varies from instant to instant (Lombard, 2000, cited in Straaten, 2000) does not exclude the possibility that presence is a continuous phenomenon or variable. Some authors argue that it would be better to consider the user to feel present in both the VE and her physical surrounding at the *same* time (Slater et al., 1994). In this case, the experience of a high level of presence in the VE is related to a simultaneously low level of presence in the user's physical environment, and a high level of presence in the physical world indicates a simultaneous low level of presence in the VE. Witmer and Singer (1998), argue that the level of presence experienced in VEs is dependent upon the user shifting his attention from the physical environment to the VE. Attention, as well as a number of other factors, influences the user's involvement with the VE. This does not mean that the person no longer has any sense of being in the physical world, but as the majority of attentional resources are being spent on information coming from the VE the user will feel *more* present in the VE than in the physical world.

1.1.2 Characteristics of Presence

In their article "At the heart of it all: The concept of presence", Lombard and Ditton (1997) performed a review of the existing literature on presence identifying six perspectives on the phenomenon:

1. *Presence as social richness*: Social richness refers to the capabilities of the medium to induce a sense of "real" or "natural" social interaction in the VE including such elements as intimacy and immediacy. Presence is thus defined as "the extent to which a medium is perceived as sociable, warm, sensitive, personal or intimate when it is used to interact with other people".

[9] This implies that also Vorderer et al. (2003) may believe that one can only feel present in either the physical world or the VE at either one time.

2. *Presence as realism:* Realism refers to the capabilities of the medium to produce "representations that look, sound, and feel like the "real" thing". Lombard and Ditton further elaborate on this definition to include the distinction between social realism and perceptual realism. For example, a science fiction movie may be low in social realism as the events in the movie would be unlikely to take place in the real world, but high in perceptual realism as the characters and objects of the movie would look and behave in a manner consistent with real characters and objects. The opposite may be the case for cartoons.

3. *Presence as transportation*: Transportation refers to the perceived location of the user while interacting with the medium. The phrase "you are there" indicates that the medium has transported the user from the physical world to a virtual space where the current (mediated) events are taking place. In contrast, the phrase "it is here" indicates that the virtual space created by the medium (and user) is brought to the user that is, the user responds directly (i.e., physically) to virtual stimuli as if they were actually present in their immediate physical environment. A third phrase, "we are together", indicates the feeling of a shared virtual space such as those experienced in Massive Multiplayer Online Games (MMOGs).

4. *Presence as immersion*: Immersion here refers to both perceptual and psychological immersion. Perceptual immersion indicates the degree to which one's sensory input channels are captured by information from the virtual environment. Psychological immersion is concerned with the degree to which the user is involved and engaged with the VE, and absorbed in it.

5. *Presence as social actor within medium:* This definition refers to the phenomenon of interacting with virtual objects, including agents[10], as if they were real social entities. This may include responding to people on television, digital game avatars, and such phenomena as the Japanese Tamagotchi[11].

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[10] An agent is a computer-generated character.

[11] The Tamagotchi is a virtual pet in the shape of a small computer that demand frequent 'care' to "survive".

6. *Presence as medium as social actor*: This definition is distinct from the definition above (social actor within medium) in that it is no longer the objects or representations within the medium that are treated as social entities, but the medium itself: "....the users ignore the mediated nature of a communication experience. Basic social cues exhibited by the medium lead users to treat the medium as a social entity". For example, in a study conducted by Nass, Steuer, Henriksen, and Dryer (1994, cited in Lombard & Ditton, 1997) subjects evaluated a computer's performance in a tutoring task more favourably when the tutor computer was praised by a different computer than when it praised its own performance.

By examining these conceptualizations of presence and looking at the commonalities between them, Lombard and Ditton arrive at a definition of presence as "the perceptual illusion of non-mediation". They use the term 'perceptual' to refer to the involvement of sensory and cognitive, as well as affective processing systems. As these systems fail to recognize the mediated nature of the VE experience, an illusion of non-mediation occurs and the user feels present in the VE. In this view, the experience of presence is highly influenced by the degree of *transparency* of the medium (Lombard & Ditton, 1997; Steuer, 1992). Transparency is achieved when the medium is able to simulate real experience, that is, when the user forgets that the nature of the environment he or she feels present within is different from his or her immediate physical environment. This can happen in two ways: 1) the medium itself appears transparent to the user, or 2) the medium appears to be transformed into something other than a medium (e.g., a social entity) (Lombard & Ditton, 1997).

Lombard and Ditton (1997) also list a number of media- and user-characteristics that influence presence. Two main categories of media characteristics are described: *media form* and *media content*. Media form includes 'sensory breadth' and 'sensory depth'[12]. Sensory breadth involves the amount of sensory stimulation provided by the medium. For example, listening to a narrated story would provide auditory stimuli only while watching a movie would provide both auditory and visual stimuli. Digital games would involve an additional degree of interaction with the medium itself in terms of user control while VR simulators

[12] Steuer (1993) refers to 'sensory breadth' and 'sensory depth' as 'vividness'.

may further involve tactile stimulation and proprioceptive feedback. Sensory depth, or the nature and quality of such sensory stimulation, also influence the immersive quality of the medium. These factors involve visual display characteristics such as image quality (e.g., resolution, colour, sharpness etc.), image size, motion, camera technique, three dimensionality (3D), auditory characteristics such as sound quality (frequency range, dynamic range, signal to noise ration etc.), olfactory input, body movement, tactile stimuli, and force feedback among others[13]. Medium content refers to characters and objects, scenery, story, opportunities for action etc. Lombard and Ditton identify three content factors as particularly important for inducing a sense of presence in the user of VEs: *social realism*, use of *media conventions*, and the *nature of task or activity*. As discussed above, social realism attempts to remove traces of artificiality and 'non-realness' of the social context of the VE. User characteristics that may influence the experience of presence in VE include; willingness to suspend disbelief, knowledge of and prior experience with the medium, personality type, personal interests, cognitive style, level of sensation-seeking tendencies, need to overcome loneliness, mood, age, and gender among others (e.g., Heeter, 1992; Kim, 1996, cited in Lombard & Ditton, 1997; Slater & Usoh, 1993; Steuer, 1995, cited in Lombard & Ditton, 1997; Richardson, 1977, cited in Lombard & Ditton, 1997; Zuckerman, 1994, cited in Lombard & Ditton, 1997).

IJsselsteijn and Riva (2003) summarize the factors proposed by Lombard and Ditton (1997) under two headings: physical presence and social presence. *Physical presence*, they say, relates to the sense of being physically[14] located in the VE and *social presence* as the experience of being in a VE together with other social entities such as human- or AI-controlled avatars[15]. These authors further introduce the concept of *co-presence*, the "sense of being together in a shared space" (p.7) as incorporating the characteristics of both physical and social presence[16].

[13] For VEs where such qualities are not *physically* present (e.g., daydreaming, and possibly books that don't contain images/illustrations), sensory depth refers to the degree to which an individual is able to generate such imagery (and sensations) by the use of his or her imagination.
[14] The term physical is here used to describe the user's feeling of being physically, or bodily, present in the VE similarly to how we feel anchored in the real, physical, world by our bodies in our everyday lives.
[15] An avatar is the graphical (and visually available) representation of the user's or agent's (see footnote 11 of this chapter) 'self' or character.
[16] This is similar to Lombard and Ditton's (1997) notion of present as transportation: "we are together".

Steuer (1993) argues that, in addition to 'sensory breadth' and 'sensory depth' (i.e., 'vividness'), *interactivity* also influences the sense of presence experienced in the virtual environment. He defines interactivity as "the extent to which users can participate in modifying the form and content of a mediated environment in real time" (p.14). In this case interactivity refers to something different from 'engagement' or 'involvement' in that it is based on the objective qualities of the medium: speed, range, and mapping. Speed refers to "the rate at which input can be assimilated into the mediated environment", range means "the number of possibilities for action at any given time", and mapping is "the ability of a system to map its controls to changes in the mediated environment in a natural and predictable manner" (p.15). Sheridan (1992) summarises the above factors as the extent of sensory information presented to the user, the level of control the user has over the various sensor mechanisms, and the user's ability to modify the environment.

To conclude, the traditional view considers the 'subject' and the 'object' as representing two distinguishable domains of human experience: 1) the mental domain and 2) the physical domain. This distinction also allows for a separation of the 'virtual' from the 'real'. From this perspective, presence is defined as the phenomenological experience of 'being in' a VE. This experience involves being (mentally) transported to and feeling (physically) present within a virtual space rather than in one's immediate physical environment. For this process to occur, the medium is experienced as 'transparent' to the user. By distinguishing between the mental and physical domains, researchers within the traditional framework can compare the experience of presence in a VE to the experience of presence in the real world. Further, both subjective (i.e., the user) and objective (i.e., the medium) aspects of the presence experience can be studied. User factors involve sensory, cognitive, and perceptual systems that seem to affect users' experience of presence in VEs, as well as personal interest, willingness to suspend disbelief and so on. The medium can be studied according to media form and media content, as well as by the possibilities for interaction offered by the technological system.

1.2 The Ecological Approach

The last decade of presence research has involved an increased interest in applying ecological ideas to guide our understanding and measurement of presence. These ideas originate from Heidegger's (1967) phenomenological existentialism[17] and Gibson's ecological approach to visual perception (Gibson, 1979, cited in Van der Straaten, 2000; Gibson, 1986). A combination of ideas taken from these writers' works has been combined in the presence literature to produce a new theoretical framework for presence research (e.g., Van der Straaten, 2000; Zahoric & Jenison, 1998). This ecological framework focuses on Heidegger's notion of existence as "being-in-the-world" where perception and interpretation exist in an interdependent relationship with the environment. A similar interdependent relationship is highlighted in Gibson's theory of *affordances*. In his view, perception is a continuous process that is driven by the possibilities for action offered by the environment, called affordances. In the following section we will take a closer look at the underlying meaning of these concepts and their relevance for presence research.

1.2.1 Heidegger and the Transparency of Objects and Human Interactions

Heidegger (1967) stressed that the only way of knowing about the world and its phenomena is by acknowledging the non-separable and interdependent relationship between our subjective selves and the world around us. In this view, the 'subject' and the 'object' cannot be separated and complete objectivity is never possible. In other words, our "being-in-the-world" cannot be separated from the experience of objects. Zahoric and Jenison (1998) describe the Heideggerian notion of "being-in-the-world" as being: ""thrown" into situations in which we must continuously act and continually interpret" (pp. 82-83). According to Heidegger (1967), the phenomenological experience of being present in the world involves the constant and continuous coupling of action, or activity, and interpretation. Within this

[17] Phenomenological existentialism here refers to Heidegger's theory of human being and existence.

view, both full conscious awareness[18] and complete unawareness are at all times ruled out as possible psychological states in which humans can find themselves. Interpretation, at either an unconscious or conscious level, is always present, and we can never be entirely detached from, and analytic about, the world that we live in. Thus, interpretation serves as a "filter" through which all human experience is mediated.

According to Heidegger, the notion of "being-in-the-world" is what determines our feeling of presence in a world or environment. This understanding of everyday existence also implies that humans are not capable, in the everyday flux of action, of having stable mental representations[19] about the world that we live in. From the Heideggerian perspective, "representation is interpretation" (Zahoric & Jenison, 1998, p. 83). As we are continuously "thrown" into situations in which we act we are unable to detach ourselves from that situation and produce stable representations of that situation and the objects within it. As we interact with objects in the world, both our actions and the objects themselves become part of this state of flux[20]. Instead of creating a stable mental representation of an object it becomes *transparent* to the user. The object is conceived of only in terms of its usefulness related to the task at hand, a phenomenon Heidegger termed "ready-to-hand" (Packer, 1985). From a Heideggerian view then, presence is characterized by a sense of "being-in-the world" where objects are "ready-to-hand" and transparent to the individual. Thus, Heidegger views mental representation as a secondary component to our everyday existence. Mental representations occur as follows: Sometimes in our interaction with objects a "break-down" of the continuous state of flux occurs, a state called "unready-to-hand". This is in situations in which the object ceases to be "ready-to-hand" and "breaks out of" the state of flux. In the

[18] Complete awareness here refers to the idea that a person can be conscious of (and analyze) phenomena in the world separate from the influence of the environment (i.e., operate in the mental domain only). For rationalists, the separation between mental and physical domains allows for conscious awareness to exist separate from the physical world. For Heidegger, this notion is considered a false notion.

[19] Stable mental representations here refer to the rationalist idea that mental representations exist separate from the world of objects. That is, they are detached from the physical world and may therefore be viewed as constituting stable properties existing within the mental domain. But for the Heidegger, the continuous and interdependent relationship between the person and his or her environment excludes the possibility of having stable mental representations about the world as such mental representations are necessarily always changing as a result of this interaction (and state of flux).

[20] A state of flux refers to a phenomenon that is in constant change. In this case, both objects in the world and our actions are in constant change due to the moment-to-moment interaction between the environment and the person, and the interdependent relationship between the two.

"unready-to-hand" state, particular characteristics of the object or situation will stand out, but only in relation to the background of the activity itself. As we detach ourselves from the activity at hand the object becomes "present-at-hand" and *non-transparent* to the user. Heidegger (1967) uses hammering as an example to describe this process: "it is only in situations where the hammer slips or breaks or misses its target that the properties the hammer possesses, other than those normally utilized for the concernful action of hammering, are revealed-become 'present-at-hand'" (Zahoric & Jenison, 1998, p. 84). A "break-down" in the condition of "throwness" or flux can create temporary mental representations of the situation at hand. As mental representations are viewed as an abstraction away from our "being-in-the-world" it also necessarily removes us away from the phenomenological experience of feeling present in that world. Thus, any factor that may "break" the continuous and phenomenological experience of being present in an environment may reduce the user's sense of presence in that environment. Examples relevant for the interaction with VEs include, among other things, hearing the phone calling in the user's physical environment and time lags within the VE.

1.2.2 Gibson and the Role of Affordances

J. J. Gibson's ecological approach to visual perception shares some ideas with Heidegger's emphasis on the interdependent relationship between a human, or animal[21], and the environment. According to Gibson, "perception is a direct process of picking up information from an informationally rich environment" (Zahoric & Jenison, 1998, p. 85), or in Gibsonian terms, "extracting of invariants from the stimulus flux" (Gibson, 1986, p. 3). The environment is not a 'physical' environment as described in terms of geometrical space and atoms within the natural sciences, but an environment that exists interdependently with the perceiving animal[22]. Instead of describing it in terms of common physics, Gibson chose to

[21] Gibson used the term animal rather than human to include all living organisms that perceive and behave.
[22] According to Gibson the environment includes the animal's surroundings, which contain substances, surfaces and their layout, enclosures, objects, events, and other animals.

describe it in terms of a layout of surfaces[23]. Information about the environment is obtained through the illumination of surfaces and through the 'ambient optic array'. The ambient optic array produces structured information about the environment that can be perceived by the animal, or human, as a result of the functional properties of the eye and brain. Further, the environment consists of both invariants and variants (i.e., permanence and change): "The main invariants of the terrestrial environment, its persisting features, are the layout of its surfaces and the reflectances of these surfaces" (Gibson, 1986, p. 87). Perception, existence, and a sense of presence in the environment are therefore dependent on both the structural-functional properties of the environment and the structural-functional properties of the animal. Gibson argues that these structures of the environment are perceived in terms of the possibilities they offer for action, or *affordances*. The hammer affords hammering and the ground affords walking. Thus, not only does perception involve direct access to the environment, but also direct access to the meaning or value of the "furniture" of that environment when it is perceived in relation to the self or the surfaces of the body (e.g., the cliff is fall-off-able, the chair is sit-on-able). It is important to note that these affordances are dependent on both the animal and the environment so that while the surface of the water is walk-able for a small insect it is not so for a human. These affordances have been developed and provided by the environment in coordination with the evolution of the organism; "As a result, perception for the organism is the pickup of information that supports action, and ultimately evolution" (Zahoric & Jenison, 1998, p. 85).

Similar to Heidegger then, Gibson focuses his theory on the interdependent relationship between the animal, or human, and the environment. As a function of this interdependency we may feel present in the environment. That is, our experience of being in the world is produced by the interdependent relationship between affordances provided by the environment and the human's direct access to information of these affordances. Zahoric and Jenison (1998) see a strong similarity between Gibson's view on the interrelationship between the animal and the environment and Heidegger's notion of interpreter and interpreted. Within this view, representations of the environment are superfluous in terms of

[23] Surfaces are what lie at the boundary between different *substances* and *media*. For example, the surface of a rock is a surface because it is at the boundary between rock (solid substance) and air (medium). The surface of the sea is a surface because it is at the boundary between water (medium) and air (medium).

experiencing presence in the environment, as presence is a result of *direct* information pickup and possibilities for action. Imagery, Gibson (1986) argues, is distinct from what is actual, or real, because it can only be perceived in terms of information that has already been picked up from the environment[24]. The imaginary captures a 'second-hand' version of reality more similar to a photograph than to what is real. According to Gibson, the real and the imaginary are specified by two different modes of operation of the perceptual system. For example, it is not 'cognitive maps' that help us orient ourselves in the world, but it is the direct perception of "being everywhere at once" (p. 199): "The perceiving of the world entails the co-perceiving of where one is in the world and of being in the world at that place" (Gibson, 1986, p. 200)[25].

It is important to note that, although the Heideggerian and Gibsonian views are here considered under the same heading, strong differences exist between the two perspectives. Biocca (2001) argues that Gibson's ecological theory of perception can be interpreted as a realist[26] position of reality and thus as a theory that emphasises the existence of a physical reality even when that reality is not perceived by the human. As mentioned above, Gibson considered invariant properties of the environment to be necessary for perception to occur. Thus, although such invariants refer to the structures created by the reflectance of surfaces through the ambient optic array rather than 'real', 'physical' objects per se, the idea of invariants opposes a strong relativist argument for presence. That is, the role of invariants indicates a belief in stable, 'physical' properties in the world. In contrast, Heidegger opposes the separation of mental and physical domains and holds that our experience of 'being-in-the-world' can only be understood as the result of an interdependent relationship between the human and his or her environment that involves the constant and continuous coupling of action and interpretation. That is, our 'being-in-the-world' is not dependent on the direct pick-up of information from the environment, but on action, perception, and *interpretation*. Thus, whether the environment contains any 'physical' properties as such does not seem to

[24] Gibson uses the term 'real' to refer to that which is characterised by the direct (sensory) access to information about environmental affordances. As such, imagery is an abstraction *away* from the real as it is something the individual experiences in exclusion.

[25] As such, imagery and mental representation is viewed more as a by-product of presence rather than as a pre-requisite for it.

[26] Realism refers to the theory that physical objects continue to exist when not perceived (the rationalist perspective grew out of this view). Gibson himself sometimes refers to his position as 'direct realism'.

be particularly important for Heidegger. Rather, it is the interdependent relationship between this environment and the human that makes the experience of presence occur (and that also make it possible to talk about an environment in the first place that is, the environment would not exists if the human was not there to experience it). Heidegger's ontological position can thus be said to contain a stronger relativist element than that of Gibson. Nevertheless, the commonality between Heidegger and Gibson is still evident as both writers focus on the interdependent relationship between human action and perception, and the environment

1.2.3 A New Definition of Presence

The ecological view has had a strong influence on the study of presence in VEs. Not only has it provided a different theoretical framework for defining presence, but it has also influenced the technological architecture of VE designs by having researchers pay great attention to the construction of affordances. By using the works of Heidegger and Gibson, Zahoric and Jenison (1998) propose a new definition of presence: "Presence is tantamount to successfully supported action in the environment" (p. 87). By "successfully supported" action in a VE, they mean that actions being afforded by the VE and executed by the user follow the same laws as action in our everyday environment. The affordances offered by the VE must fit with our already developed perceptual system. When affordances offered by a VE fail to follow the lawfulness of real, everyday perception/action coupling, the user's experience of presence in that VE may "break" or be reduced[27]. Flach and Holden (1998) suggest that a VE's ability to simulate real perception/action coupling in terms of affordances can therefore serve as a tool for measuring presence in VEs. Interestingly, the proposition offered by Flach and Holden to compare perception/action coupling in a VE to perception/action coupling in the real world is reflective of a rationalist view of reality rather than an ecological view. While the rationalist view separates physical (i.e., real) and mental

[27] While the traditional view often discusses presence in VEs as an "either/or" experience, others emphasize the "transportation" of real world developed patterns of perceptual processing to the VE where they function as if that environment was the same as the original.

(i.e., virtual), the ecological view does not[28]. In contrast, for ecologists it is the immediate and continuous interaction between the human and his or her environment, whether that environment is considerer real or virtual, that is the topic of interest. Thus, although the ecological view offers a new framework for *understanding* presence, Flach and Holden's suggested method of measurement for presence still remains within a rationalist framework.

To conclude, the ecological view, including the view of both Heidegger and Gibson, focuses on the interdependent relationship between the human and his or her environment. Although Heidegger holds that the 'subject' cannot be separated from the 'object', Gibson's view on this issue seems to lean more towards a rationalist position of reality (Biocca, 2001). Biocca argues that assigning Heidegger's notion of non-separable physical and mental domains to Gibson's writings is questionable due to Gibson's emphasis of the role of environmental invariants. Interestingly, the majority of presence literature that discuss the ecological view of presence most commonly hold on to the rationalist distinction made between the 'real' and the 'virtual'. This is evident in theories of presence such as Sheridan's (1999) estimation theory and the embodied cognitive framework (see below). Further, there seems to be a common trend among presence researchers to focus their inquiry on the way we come to feel present in an environment and how we come to know about that environment, rather than on the nature of reality per se. Thus, the ecological view (including both Heideggerian and Gibsonian ideas) seems to offer new ways of interpreting the presence phenomenon rather than a completely new framework of presence per se, as the presence phenomenon discussed seems to remain anchored within the traditional framework. A more thorough criticism of the meshing of different ontological and epistemological views to describe presence is beyond the scope of the present thesis. Instead, this section focuses on how the ecological view of presence borrows from both Heideggerian notions of "being-in-the-world" (including both "present-at-hand" and "unready-to-hand" states), and from Gibson's idea of affordances to understand the experience of presence in VEs. The definition of presence proposed by Zahoric and Jenison (1998) matches these ideas.

[28] Although Gibson may recognize the existence of 'physical' qualities of the real environment, he still holds that the only way of understanding our experience of being in that environment is through the interdependent relationship between the human and the environment.

1.3 Estimation Theory

According to Sheridan (1999), rationalist and ecological views of presence can be unified within an estimation theory paradigm. Sheridan argues that reality can never be known due to sensory and action constraints, it can only be estimated. By applying the estimation model commonly used in engineering, he attempts to show how the rationalist and ecological frameworks can be combined into one unified theory of presence. From an estimation theory perspective, we continuously generate and adjust a mental model which estimates reality. This occurs through sensory and activity "filters" that bridge the internal subjective world with the "outside" objective world. Our acting in the environment provides us with access to information about the affordances offered by that environment, and this information is what is filtered through the sensory and action filters to continuously update our estimated reality.

Although Sheridan attempts to join rationalist and ecological views, his 1999 article on the estimation theory of presence does not escape having a strong underlying Cartesian feel (Biocca, 2001). Not only is reality viewed as being "out there" and unknowable[29], his discussion of sensors and estimators to gain (estimated) access to this reality imply the materialistic presence of such sensors (Biocca, 2001). Further, Biocca (2001) criticizes Sheridan (1999) for using a relativist argument to support the union of Cartesian and ecological views of presence. As Biocca (2001) notes, Gibson's theory of perception involves detecting and extracting invariant properties of the environment which are not "estimated or constructed in any relativistic meaning of the term" (p. 549). In addition, Sheridan's focus on mental models removes his theory away from Heidegger's notion of 'being-in-the-world'. Thus, the incorporation of ideas from the ecological framework within an estimation theory view of presence seems to raise more issue than it manages to solve.

[29] This view of reality can also be said to reflect a Kantian view.

1.4 The Embodied Cognitive Framework

Following both rationalist views and Gibson, the embodied cognitive framework proposes a relatively new view within cognitive psychology expanding the ideas of information processing theory towards understanding the mind "in the context of its relationship to a physical body that interacts with the world" (Wilson, 2002, p. 625). Within this framework, the conceptualizations of perceptual and motor processes as input and output devices have been transformed to include such ideas as Gibson's 'affordances' and the possibilities for action in the environment. Most importantly, this theory proposes that our mental representations about the world are interdependently linked to our acting in the environment[30]. In contrast to Heidegger and Gibson who focus their discussion of presence in an environment on the direct and continuous interaction with that environment, the embodied cognitive framework highlights the necessity of mental representations in managing one's interaction with the environment. Glenberg (1997) describes this combined action-based and cognitive interaction with the world as follows:

> Patterns of action derived from the projectable properties of the environment are combined (or meshed...) with patterns of interaction based on memory. The two patterns can combine because they are both embodied, that is, both are constrained by how one's body can move itself and manipulate objects. The resulting pattern of possible actions is conceptualized: the possible actions for that person in that situation.
>
> Thus meaning of an object or a situation is a pattern of possible action (p.4).

As such, the embodied cognitive framework uses a combination of Gibsonian theory and mental model theory to arrive at a description of human experience that is intrinsically linked to the phenomenological experience of having a body. In this way, cognitive representation is thought to consist of possible patterns of actions in the environment (Schubert, et al., 1999). The notion of projectable properties refers to properties that are actively created[31] by

[30] The acknowledgement of both mental and physical domains anchors this theory within a rationalist framework.
[31] Projectable properties is considered to be 'actively created' due to the interdependent relationship between the structural-functioning properties of the environment and the structural-functioning properties of the brain involved in the process of perception.

the person during *direct* sensory perception, resulting in mental representations of the situation. Non-projectable properties are those derived from memory and these are meshed with the projectable properties to fully understand the situation at hand (Schubert et al., 1999)[32]. Schubert et al. use this framework to discuss the sense of presence, or embodied presence, experienced in VEs. In their view, VEs provide mediated information that, for presence to occur, must be processed in the same way as non-mediated information is processed in the physical environment. The representations of "meshed sets of patterns of action" (p. 3) that are possible in the VE are created while the user suppresses non-mediated information arriving from the user's physical environment (e.g., visual and auditory information originating 'outside of' the VE): "Presence should involve at least two components: One component related to the suppression of the actual environment and the focusing on the VE, and a second component related to the mental construction of a space out of the VE in which the body can be moved." (Schubert et al., 1999, p. 5). Thus, this process involves the construction of a mental model[33] of the virtual space and perception of the possibilities for action that this space possesses. Due to the role of the body in interacting with the environment, Schubert et al. assume that navigation of the body (i.e., virtual body or avatar in VEs) is the most important form of interaction taking place: "Presence develops from the representation of navigation (movement) of the own body (or body parts) as a possible action in the virtual world" (p.4)

Embodied cognitive theory assigns the role of the body, and the sensory channels it contains, a much greater role in describing human psychological experience than the traditional or the ecological views. The physical body becomes a medium through which mental representations and action occurs. Cognition is situated (i.e., anchored in the environment by the body) (Wilson, 2002), it takes place within an environment, and involves both perception and action. Even types of cognition that appear to be active independently of the environment, such as imagery and memory, are here viewed to be grounded in sensory processing and motor control (Wilson, 2002). This is because such environment-independent

[32] This is similar to Kosslyn's (1999) theory of visual perception which will be discussed in more detail in chapter 3 of this thesis.
[33] The idea of a constructed spatial model of the environment is also reflected in Vorderer et al.'s (2004) spatial-functional model of (spatial) presence which will be discussed in more detail in chapter 2 of this thesis.

processes evolved as a result of the human interacting with the environment. This idea of mental imagery can be understood in two ways: 1) Imagery is based on previously obtained information from the environment, it is grounded in the evolution of sensory processes and bodily action within the environment, and can be considered a "by-product" of this evolution, and 2) imagery is a necessary component of sensory processing itself and as an integrated part of the perceptual system[34]. Although, at first glance, these views may seem to suggest opposing ideas, they are in fact consistent: If imagery is considered an integral part of the perceptual system and a component of sensory processing, it will necessarily also have been affected by the evolution of sensory processes and bodily action within the environment. Imagery is a by-product of this evolution merely in the sense that it could only have evolved as a result of the body being situated in and interacting with the environment. According to the embodied cognitive framework, imagery information is stored in memory and this information serves to assist the sensory processes in detecting and perceiving information coming from the environment (i.e., projectable properties are meshed with non-projectable properties to provide patterns of possible actions). The processes involved in this function have evolved in accordance with the related sensory and perceptual processes.

Biocca (2001) argues that the best way of conceptualising presence is as a subset of the mind-body problem. The presence literature focuses its discussion on the experience of "*being here or there*" rather than of "*being as such*", which means that "the fundamental issue at the root of the problem of presence is the perception of reality, usually under the domain of epistemology, not reality itself, usually discussed under the banner of ontology" (p. 550, italics in the original). Further, Biocca argues that investigating presence from a philosophy of mind perspective helps to "address the fundamental epistemological problems of perception and consciousness raised by the technologies of presence" (p. 552). Thus Biocca places great importance on the mind-body problem and theories of sensation and perception to understanding presence. Biocca refers to Loomis' (1992, cited in Biocca, 2001) discussion of presence within a distal attribution framework to emphasis this point. Distal attribution theory discusses why the proximal sensation of light on the retina is experienced as objects in space rather than as a sensation on the surface of the eye:

[34] Also see the ideas of Kosslyn (1996), discussed in chapter 3 of this thesis.

> The experience is attributed to the distal stimulus of the object out there and not a proximal stimulus at the surface of the body, the retina.
>
> Determining the location of "objects out there" during the distal attribution, simultaneously locates the body "here" surrounded by these objects. When a display technology creates the energy array that forms the proximal stimulus, the objects "out there" are virtual objects. But, just as in the perception of energy arrays originating from the physical environment, extracting the invariants creates a "viewpoint" of the body – but one that is situated inside the virtual scene (Biocca, 2001, p. 552).

Thus, as a user of a VE perceives the objects within that VE the user will locate his or her (virtual) body in relation to these objects. That is, his or her body will be perceived as being located in the VE rather than in the physical environment. This experience of being (bodily) located in the VE will influence the degree to which the user feels present in that VE. The experience of presence in the VE may be mediated by the technology of the medium by affecting the user's senses and motor channels. Thus, the body in this case is a mediated, or virtual, body (i.e., it is located in the VE), and through this virtual body the user can feel present in the VE. Biocca argues that this framework reflects Heidegger's notion of objects as "ready-to-hand" where the VE and objects within the VE becomes a natural extension of the body. In addition, this view allows for a Gibsonian interpretation of consciousness as it can be studied through investigating the relationship between the optic array (as created by the technology) and the individual.

To conclude, the embodied cognitive framework attempts to bridge ideas from the traditional and ecological views of presence while at the same time recognising that its underlying framework remains within the rationalist tradition. The embodied cognitive framework argues that the experience of presence in an environment occurs as a result of the interaction of mental and physical domains and that imagery and mental representation serve a major function in this process. This interaction, and consequently the experience of presence, is facilitated by the body and the boundaries this body contains. That is, the experience of presence in a VE occurs when the users perceives their body to be located in the VE.

1.5 The Socio-Cultural View

Mantovani and Riva (1999) argue against the rationalist, dualistic view and the assumption that reality can be described by separating external (objective) reality from the inner (subjective) world. In their view, the rationalist stance implies a view of VEs as socially shared *hallucinations* where the perceptual system is led to believe that the illusory surroundings are in fact 'real'. In contrast to this dualistic view of reality, they argue for a conceptualization of presence based on social construction:

> "Reality" is not out there in the world, somewhere "outside" people's minds, escaping social negotiation and cultural mediation; reality is co-constructed in the relationship between actors and their environments through the mediation of the artefacts.... If we arrive to view reality as socially constructed – language is the most precious tool we have, as it circumscribes and structures the realm of "reality", assigning precise places to things, actors, actions, and even intentions – then we realize that all the experience that social actors can have of environments, both "natural" and "artificial", is mediated. (p. 541)

Thus, both environments and presence are seen as "relational and interactive" (p. 541). All experiences are mediated through environmental and psychological "tools" (e.g., language) and it is this mediation that brings meaning to our lives as they are interpreted and understood within a socio-cultural context. The authors acknowledge the ecological emphasis on the interdependent relationship between the individual and her environment, but argue that viewing presence as social construction expands the ecological view to include the socio-cultural dimension of experience[35]. Adding to the role of mediation and the socio-cultural context is the recognition of ambiguity in everyday life[36] and the role played by culture in clarifying the meaning of human action and interaction. From this, Mantovani and Riva (1999) arrive at three main components of presence:

1. Presence is always mediated by both physical and conceptual tools that belong to a

[35] Biocca (2001) criticize Mantovani and Riva (1999) for misusing Gibson's theory of perception within a relativist framework of human experience (see section 1.2.2 for a related discussion on the differences between the works of Gibson and Heidegger).

[36] Mantovani and Riva (1999) consider everyday situations to be ambiguous due to the continuous flux of interaction between the interest of actors and environmental affordances.

given culture.

2. The criterion for presence does not consist of simply reproducing the conditions of physical presence but in constructing environments in which actors may function in an ecologically valid way.
3. Action is essentially social (as knowledge in everyday situations is often distributed among various actors and various artifacts) (p. 547).

The authors argue that this theory focuses on the quality of VEs as spaces in which one can learn about how information in an environment is displayed and processed. A VE can be used to study action within a particular social context as it consists of an environment that can be "navigated, traversed, and engaged" (p.548). The above definition of presence also implies that for presence to occur, social dimensions such as communication, cooperation, and conflict must be accounted for as plausible consequences of VE interaction.

1.6 Conclusion

This chapter provides an overview of the main theoretical approaches applied to understanding the concept of presence. The traditional view is based on the Cartesian separation of physical and mental domains. Thus, what is considered real is our immediate physical environment as it is experienced in our everyday lives. The virtual is that which simulates the real through mental processes in combination with technological devices. From this perspective, the ability of a user to construct mental representations of a VE that 'match with' the nature of the physical environment (based on both user and media characteristics) aid users to feel present in that VE. This separation of mental and physical domains allows researchers to investigate the effects of mental processing on the experience of presence in VEs. Heidegger and Gibson both considered mental representations to be a secondary component to the experience of feeling present in an environment. Thus, the topic of investigation within an ecological view of presence is not mental processes per se, but rather the interdependent relationship between the individual and the environment. More specifically, researchers that apply an ecological view of presence investigate the affordances offered by environment and the effects these affordances have on the experience of presence in a VE. However, as I have discussed throughout this chapter, the ecological view as presented within the presence literature tends to base itself on a number of rationalist assumptions about reality. Thus, this approach can be criticised for meshing different ontological and epistemological views.

The research presented in this thesis focuses on the relationship between individual differences in spatial ability and the experience of presence in VEs. Spatial ability is a term that originates from, and that is studied within, the field of psychology. Thus, a number of rationalist assumptions about reality are made: 1) mental and physical domains are separable, 2) mental properties are important factors in the experience of presence in VEs, and 3) the experience of presence in the real world can be compared to the experience of presence in a VE. These assumptions are evident in both the traditional view and the embodied cognitive framework. Thus, the method, analyses, and interpretation of results of the study presented in this thesis base themselves on these views. Further, a rationalist view of presence allows for the use of quantitative methods of inquiry such as presence questionnaires. The next chapter will describe different ways of measuring presence in VEs that have been proposed within the traditional framework. One questionnaire in particular, the MEC Spatial Presence Questionnaire (MEC-SPQ), will be highlighted. The theory behind the MEC-SPQ presents a thorough description of how the experience of presence occurs, and is thus dealt with in more detail.

2 MEASURING PRESENCE

From a psychological point of view, presence is not a direct product of sensory stimulation, but depends on both media and user characteristics, as well as interactivity between the user and the medium, and the type of activity performed. It is a phenomenological *experience* and measurement of presence within the field of psychology thus often focuses on the person interacting with the virtual environment (VE) rather than on the medium facilitating that environment. However, this experience is always to be seen in light of the immersive qualities provided by the medium. The most common methods used within psychology to address this issue involve subjective[37] measures such as questionnaires. Other measures, such as behavioural and physiological measures, have also proven to be useful when wanting to find out more about the degrees to which people experience a sense of presence in different VEs. Thus, presence measures can also help to define the presence construct itself. Lombard and Ditton (1999) highlight the distinction made between 'physical presence' and 'social presence' where 'physical presence' refers to the actual physical sense of feeling present in a VE and 'social presence' refers to the experience of the VE as a social place. It is the former sense of feeling physically, or bodily, present in the VE that underlies the examples of presence measures discussed in this chapter. In the study described in this thesis, the researcher applied the MEC Spatial Presence Questionnaire (MEC-SPQ) to measure presence. Thus, particular attention will be paid to this measure.

2.1 Subjective Measures

A number of subjective measures have been developed in an attempt to measure the experience of presence in VEs. Self-reports in the form of questionnaires, interviews, or continuous self-monitoring[38] have been suggested. Questionnaires often ask the person to rate his or her experience of presence in the VE using numerical scales such as Likert scales,

[37] The term 'subjective' is here used to refer to measures that acquire some level of self-report by the user.
[38] Continuous self-monitoring requires users to rate fluctuations in their sense of presence during the actual experience (e.g., by the means of a slider-button, see IJsselsteijn & De Ridder, 1998)

while interviews or reports use directed, open-ended questions to elicit user's experience of presence. Thus, such measures provide an indication of users' experience of presence in VEs. Most questionnaires and interviews are delivered or conducted after the person has already interacted with the VE (i.e., post-immersive). When directly based on theories of presence such questionnaires seem to have good face validity. However, as the concept of presence has many and varied definitions, questionnaires developed on one specific theoretical basis have one major limitation - they may exclude important contributing factors to the presence experience not accounted for in the theory in question. Thus, a major challenge for future researchers is to develop an agreed upon definition of presence so that appropriate measures can be developed. Questionnaires have an advantage in that they do not interfere with the actual moment-to-moment experience of the VE. However, the user's responses may be affected more by the period of VE interaction just prior to the questionnaire being administered than by the early part of the VE experience. In addition, questionnaires do not manage to tap into the continuous change in presence levels that occur throughout the entire VE experience. They are also restricted to ask questions related to presence of which the user is consciously aware of. However, they are easy to administer, score, grade, and interpret, and are generally cost-effective.

2.1.1 The Slater-Usoh-Steed Questionnaire (SUS) (Slater, Usoh & Steed, 1994)

Slater, Usoh, and Steed (1994) argue that both internal and external factors influence presence. A model of presence based on such factors provides the underlying framework for the SUS Questionnaire. Three main factors of presence were identified: 1) the sense of being in a VE; 2) the degree to which stimuli from the VE override stimuli from the physical environment; and 3) the degree to which the user experiences and remembers the VE as a place that he or she visited. The latest version of the SUS contains six questions that are rated on a 7-point Likert scale. These questions include: "Please rate your sense of being in the virtual environment, on a scale of 1 to 7, where 7 represents your normal experience of being in a place"; "To what extent were there times during the experience when the virtual environment was the reality for you?"; and "When you think back to the experience, do you think of the virtual environment as images that you saw or more as somewhere that you visited?". The SUS has been found to be sensitive to individual differences in presence and to distinguish between levels of presence experienced in different conditions[39] (Youngblut & Perrin, 2002, cited in Van Baren & IJsselsteijn, 2005). However, evidence of appropriate levels of reliability and validity has not been reported. Usoh, Catena, Arman, & Slater (2000) conducted a "reality-test" of the SUS where data from the VE were compared with data from the real world (the hypothesis was that the feeling of presence should be greater in the user's physical environment compared to the VE). In this test only two of the SUS items were significantly different among the two conditions and the SUS therefore did not show good discriminant validity between the two conditions.

2.1.2 The Presence Questionnaire (PQ) (Witmer & Singer, 1998)

Following the work of Sheridan (1992) and Held and Durlach (1992), Witmer and Singer (1998) developed a presence questionnaire based on a number of factors commonly associated with presence. These factors included directed attention, sensory stimulation, and environmental and individual factors that influence the person's involvement with the VE. They argue that *involvement* with a VE arises as a consequence of focusing one's attention towards the VE. As noted in the previous chapter, these authors view immersion as the psychological experience of being enveloped by the VE and presence as "the subjective experience of being in one place or environment, even when one is physically situated in another" (p. 226). Thus, in addition to the PQ, these authors developed a second questionnaire, the Immersive Tendencies Questionnaire (ITC), to assess individuals' capability to become involved and immersed in VEs. However, the PQ is by far the most widely used of these two questionnaires and will thus be the main focus of this review. Witmer and Singer wanted to arrive at a presence questionnaire that would be valid across media and content (e.g., TV, film, computer games, VR etc.) and included four categories of presence factors in their conceptualisation of presence: control factors, sensory factors,

[39] Two main conditions were examined: a projective screen and a desktop interface where the first was considered more immersive in terms of sensory stimulation than the latter.

distraction factors, and realism factors. Control factors refer to: 1) the degree of control the user has over the characteristics of the VE (such as the objects within it) and the tasks that are being executed; 2) the speed and accuracy of the VE's reaction to the user's activities in the VE; 3) the degree to which the user can anticipate what is going to happen in the VE; 4) the degree to which the type of interaction in the VE simulates real interaction; and 5) the user's ability to modify the VE (e.g., move objects, open doors etc.). Sensory factors refer to the number of different sensory channels supplied by the VE, the number and quality of sensory stimuli, the consistency of the stimuli, degree of self-movement (e.g., of the avatar), and the degree to which the user actively searches the VE with their sensors (e.g., changes view point). Distraction factors refer to the degree to which the user is fully immersed in the VE and manage to selectively attend to stimuli in the VE rather than in her physical environment. Such factors include interrupting stimuli that may arise as a consequence of the medium itself (e.g., time-lags, "clumsy" big goggles). Realism factors refer to the degree to which the VE looks and feels like the physical world. Examples of questions from the PQ include: "How much were you able to control events?"; "How completely were all of your senses engaged"; "How aware were you of events occurring in the real world?"; and "How much did your experiences in the VE seem consistent with your real-world experience?". The PQ has an internal consistency (Cronbach's alpha) between .81 and .88 (Witmer & Singer, 1998; Youngblu & Perrin, 2002, cited in Van Baren & IJsselsteijn, 2005). However, appropriate levels of validity have not been reported. The PQ has been found to discriminate between conditions in some studies (Youngblu & Perrin, 2002, cited in Van Baren & IJsselsteijn, 2005), but not in others (Youngblut & Huie, 2003; Usoh, et al., 2000). Slater (1999) and Insko (2003) suggest that as the PQ focuses on the technological characteristics of the medium it may be measuring people's *perception* of the VE's qualities rather than the actual immersive properties of the medium[40]. Further, Witmer and Singer (1998) has been criticized for assuming that sensory immersion exists in a linear causal relationship with presence.[41] Although presence can be thought of as a product of immersion (both psychological and sensory) to some degree, it does not always need the complete (or even

[40] Immersive properties of the medium include display size, sound quality etc.
[41] Sensory immersion refers to the degree to which the medium stimulates the user's sensory channels. A linear causal relationship refers to the idea that the more one's sensory channels are stimulated in accordance with real world experience, the more present will the individual feel in the VE.

close to complete) enveloping of sensory channels to occur (Schubert et al., 2001). Other factors, such as VE content, user interest, and user's imagination may influence the sense of presence experience (Lombard & Ditton, 1997).

2.1.3 The ITC Sense of Presence Inventory (ITC-SOPI) (Lessiter, Freeman, Keogh, & Davioff, 2001)

The ITS-SOPI was developed by Lessiter et al. (2001) to be used across different types of media and different types of media content. Based on previous research on presence, the questionnaire items were related to both media and user characteristics. Some of the factors considered were sense of space, involvement, realness, naturalness, perception of time, awareness of behavioural responses, sense of social interaction, personal relevance, arousal, and negative effects. The final version contains 44 items grouped under 4 main factors; 1) sense of physical space, 2) engagement, 3) ecological validity, and 4) negative effects. The latter factor, negative effects, refers to adverse physiological effects such as dizziness, nausea, headache, and eyestrain. These factors are thought to negatively influence the user's experience of presence by disrupting the flow of the VE experience and possibly remind the user of the mediated nature of their experience. Examples of items on the ITC-SOPI are: "I had a sense of being in the scene displayed"; "I felt involved in the displayed environment"; "The content seemed believable to me"; and "I felt dizzy". Individual scores on the ITC-SOPI were found to discriminate between different media (i.e., both media form and content), and all four factors were found to have good levels of reliability (Cronbach's alpha of .76 - .94). The researchers also found high correlations (.46 - .62) between the three first factors. In contrast, the negative effects factor only correlated moderately with the first factor; sense of physical space (.24). The fact that differences in scores were obtained between different media provides some support for the content validity of the ITC-SOPI. However, similarly to the PQ, the ITC-SOPI may misrepresent the effect of sensory stimulation on presence by describing this relationship in a linear fashion.

2.1.4 The Igroup Presence Questionnaire (IPQ) (2001) (Schubert, Friedmann, & Regenbrecht, 2001)

This questionnaire is based on a somewhat different theoretical model from the PQ and the ITC-SOPQ. Schubert et al. (2001) argue that the degree of sensory immersion (i.e., the number of sensory channels enveloped by the VE) does not necessarily determine the user's level of presence in a one-to-one causal relationship. Instead, cognitive processes should be thought of as mediating the relationship between sensory immersion and presence[42]. Such cognitive processes involve the construction of a spatial-functional model of the VE that allows the user to consider the VE as a 'space' that he or she can inhabit. Two cognitive processes are identified in constructing the spatial-functional model: construction and suppression. First, mediated stimuli are received from the VE. Second, cognitive processes work 'on' these stimuli to construct a mental model of the virtual space in which the user can perceive his or her body to be located. The user also constructs representations of the possibilities for action[43] provided by the VE and these representations lead the user to situate her body in the VE rather than in her physical environment. Third, incompatible sensory input from the physical environment is suppressed so that the user is attending primarily to mediated stimuli. The sense of presence is thought to reflect the construction of a mental model as 'spatial presence' and suppression as involvement. The items in the IPQ include some newly developed items as well as items derived from their own and others' previous research. A factor analysis revealed three main presence factors: 1) spatial presence (sense of being in the VE); 2) involvement (level of attention devoted to the physical versus the virtual environment); and 3) realness (how real the VE seemed when compared to the physical environment). Five other factors relating to evaluations of the immersion technology and evaluations of the interaction also emerged during the analysis. The interaction factors were included in a second study in an attempt to replicate the initial factor findings. By and large the same three main factors emerged. These three factors had an internal consistency (Cronbach's alpha) of .87. In addition, this factor structure is similar to factors that have been found in other studies, which provide some evidence of validity for the

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[42] See the section on embodied cognition in chapter 1.

[43] This idea is borrowed from Gibson's theory of affordances, albeit here viewed in a different relationship to mental representation from Gibson's ecological theory.

measure. However, levels of sensitivity, or its ability to discriminate across media and other conditions, have not been reported. It should further be noted that the research mentioned above was conducted on the original German version, and that no research has so far been conducted on the English translated version. Examples of questions of the IPQ are: "I had a sense of acting in the virtual space, rather than operating something from outside"; "How aware were you of the real world surrounding you while navigating in the virtual world?" (i.e., sounds, room temperature, other people etc.); and "How real did the virtual world seem to you?".

2.1.5 The MEC Spatial Presence Questionnaire (MEC-SPQ) (Vorderer, Wirth, Gouveia, Biocca, Saari, Jäncke, Böcking, Schramm, Bysbers, Hartmann, Klimmt, Laarni, Ravaja, Sacau, Baumgartner, & Jäncke, 2004)

Similarly to the IPQ, the MEC-SPQ uses the term *spatial presence*, as opposed to physical presence or merely presence, to highlight the spatial aspects of the presence experience. Spatial presence occurs when "part or all of a person's perception fails to accurately acknowledge the role of technology that makes it appear that's/he is in a physical location or environment different from her/his actual location and environment in the physical world" (International Society for Presence Research, 2001, cited in Vorderer et al., 2004, p. 3).

With the development of the MEC-SPQ, Vorderer et al. (2003) proposed a 'component-condition' approach to defining presence. They refer to 'components' as stable characteristics that are considered to be either present or not at any one time during the VE experience. Examples include self-location in the VE and possibilities for action in the VE. In addition they refer to 'conditions' as factors that vary during the VE experience, such as the user's degree of involvement, degree of absorption, degree of suspension of disbelief and so on. Both types of factors are thought to influence the user's experience of spatial presence. Vorderer et al. (2003) criticise other researchers such as Slater, Usoh and Steed (1994), Witmer and Singer (1998), Lessiter et al. (2001), and Schubert et al. (2001) for not having included condition variables in their models of presence. Following the component-condition approach, three main types of factors were included in the MEC model: 1) *media factors* refer to the technological characteristics of the medium; 2) *user factors* refer to the *states* and *actions*, as well as *traits* of the user; and 3) *process factors* refer to cognitive processes such as attention allocation and the controlled attentional processes involved in constructing a spatial-functional model of the virtual space (see Figure 2.1). Process factors are considered to mediate the media- and user factors in the development of a sense of presence in the VE.

As mentioned above, the authors suggest that spatial presence occurs when users' perceptual systems fail to acknowledge that their experience of being in a place is mediated by technology. Technology in this definition refers to all types of media, including books or other text-based media, film, computer games, and VR among others. The MEQ-SPQ relies heavily on theories of presence rooted in the embodied cognitive framework. As discussed in the previous chapter, this framework considers presence to be created through the perception of spatial cues provided by the VE and the construction of a spatial model of the VE based on these cues. Further, the perception of possibilities for bodily action (i.e., by the means of an avatar) within the VE leads users to experience a sense of self-location within the VE. Sometimes this experience is influenced by additional sensory information such as auditory or tactile information, but one does not necessarily need the addition of such information for presence to occur (e.g., presence through reading books). In addition, Vorderer et al. (2003) discuss the concept of 'situation awareness' to suggest that presence may also involve an "illusion of position and orientation" (p. 7). Self awareness in an environment involves both self-location and self-orientation, and these processes are thought to influence the degree to which users feel located in the VE. Following this argument, the authors propose the following definition of spatial presence:

> Spatial Presence is a binary, primarily cognitive, experience of self-locations, self-orientation and realization of action possibilities 'framed' by the media environment, in which sensory perception is focused on and mental capacities are bound by the media environment instead of the reality, and which can (but not have to) be enhanced by different sensory input and action feedbacks (p.8).

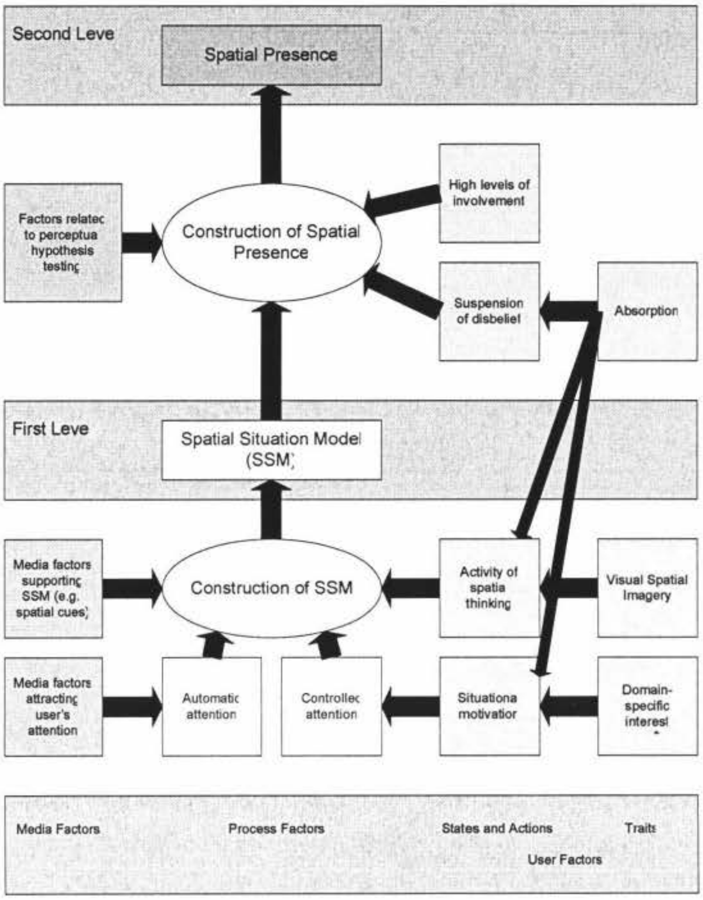
2.1.5.1 The Two-Level Model of Spatial Presence

The MEC model of spatial presence focuses on the construction of a spatial-situational model (SSM) of the VE which further leads to the experience of spatial presence in the VE by the VE user. This process occurs across two levels of processing. On the first level, different factors such as characteristics of the VE, attentional processes, and visual spatial imagery cooperate to construct a model of the surrounding environment. On the second level, this model is stabilised through the influence of high levels of involvement, suspension of disbelief and the experience of the VE as one's primary reference frame (PFR). It is through the person's PFR that perception of the surrounding environment is experienced. Figure 2.1 shows an overview of the different factors involved in producing a sense of spatial presence according to the MEC-SPQ model.

2.1.5.1.1 Level 1: The Spatial Situation Model

The first factor involved in producing a sense of presence in VEs is paying direct attention to spatial cues within the virtual simulation. This attendance to the virtual stimuli is either induced by the media or by the users themselves. Media-induced attention refers to an involuntary and automatic attention process involving either specific (e.g., user characteristics and user preferences such as how interesting the topic of the VE is for the user) or unspecific (characteristics of the medium that are "novel, or rapid or surprising" to the user such as when a big object suddenly appears in your visual field) (p. 10). User-induced attention refers to "intended and focussed processes of attention" (p.12), that is, the user intentionally attends to the virtual stimuli out of some sort of personal motivation (i.e., controlled attention). This includes the user's own intentional use of mental, cognitive, or imaginary processes such as for example when wanting to learn something new or when wanting to be entertained. Other factors include the degree to which the user wants to, and is able to, absorb himself or herself in the VE, domain specific interest (e.g., if the game played is soccer or basketball), and the user's motivation to engage intensely with, and focus their concentration on, the virtual stimuli.

Figure 2.1[44]. The MEC model of Spatial Presence.



When the stimuli of the VE are being attended to, the user can construct a spatial situational (mental) model (SSM) of the spatial environment of the VE. This process is based on user attendance to spatial cues of the VE as well as on the integration of related spatial memories and cognitions (i.e., visual spatial imagery and activity of spatial thinking). Individual differences exist in the degree of stimuli attended to, spatial memories, and cognitive abilities. Individual differences in the SSM constructed from the same VE by different people therefore occur. The individual's production of a SSM is characterized by continuous construction and interpretation. Although these two processes can be separated for

[44] Copied from Böcking et al. (2004b).

descriptive purposes, they continuously interact to create one unified model of the VE. This notion is similar to that proposed by IJsselsteijn (2002) who argues that presence involves the construction of a *complete* mental representation of the virtual space based on both bottom-up and top-down processing. Further, Vorderer et al. (2003) identify two necessary resources underlying this process; 1) spatial knowledge (pre-perceived ideas of the mediated stimuli and characteristics of the mediated space), and 2) spatial imagination (the ability to imagine objects and rooms spatially). This is similar to Kosslyn's (1996) emphasis on the combination of perceptual (bottom-up) and cognitive (top-down) processes involved in visuo-spatial perception. However, as Vorderer et al. (2003) point out, a spatial situational model of the VE is not the same as the experience of presence in the VE. While the SSM is a cognitive construct, spatial presence is the phenomenological and subjective experience of being in the mediated environment.

2.1.5.1.2 Level 2: Spatial Presence - The Primary Egocentric Frame of Reference

Based on the work of Bruner and Postman (1951, cited in Vorderer et al., 2003), Vorderer et al. offer an understanding of the development of presence based on users' unconscious or conscious decision to choose the VE, as opposed to their physical surroundings, as their primary egocentric frame of reference (PEFR). This means that users choose between competing hypotheses regarding which environment is going to provide the basis for the user's egocentric frame of reference (EFR). The EFR, also called first person perspective (FPP), is the frame of reference that locates us and our bodies within a particular environment.

Bruner and Postman's theory of perceptual hypotheses considers perception to be a "cognitive interaction between the individual and his environment during which perception of stimuli is designed and interpreted by available hypotheses about this environment" (Vorderer et al., 2003, p.15)[45]. According to this theory, the feeling of presence in VEs

[45] Thus, this theory is similar to schema theory as both hypothesise that a schema determines information seeking, storing, and recall (Voredere et al., 2003).

results from the continuous interaction of perceiving the virtual stimuli and expectations of what those stimuli represent. These 'expectations' are rooted in stored spatial memories and cognitive processes which function to update the mental representation of the virtual space. Included in this process is the continuous hypothesis-testing of whether the expectations made fit with the actual perceived stimuli. If not, then new spatial memories are accessed to improve and correct the representation of the VE. Whether a hypothesis is verified or not depends on the strength of the hypothesis in question. The hypothesis' strength is influenced by five factors: the frequency of prior confirmation, the number of alternative hypotheses available, and cognitive, social and, motivational impacts (p. 17).

Vorderer et al. view spatial presence as the experience of being in a specific spatial environment. Further, the experience of space is developed by continuously constructing a spatial model of the PEFR. When interacting with a VE, competing egocentric frames of references will be evident; one located in the VE and one that is located in the physical environment. Feeling present in a VE, as opposed to in the physical world, is dependent on choosing the hypothesis that supports the user's PEFR being located in the VE. When interacting with a VE, the spatial representation of the VE, as mentioned above, is continuously updated so that our experience of the virtual space as a space in which we find ourselves located, is stabilized. Thus, spatial presence occurs "when the hypothesis that the spatial cues of the media offer indicate the PEFR is stabilized" (p.18). The authors refer to this phenomenon as the "media-as-PEFR-hypothesis" (p.18). The degree to which the PEFR is stabilized depends on supporting and contradicting evidence for this hypothesis. For example, if I'm playing a computer game and someone in my physical surroundings asks me what time it is, I'm likely to change my PEFR from being in the VE to that of the physical environment where my friend is standing (supporting the real environment as PEFR and contradicting the VE as PEFR). It should be noted that this theory of PEFR and hypothesis testing suggests that one's PEFR can only be in either the VE or the physical environment at any one time, but never in both. Thus, according to Vorderer et al., spatial presence cannot be experienced in the VE and the physical world simultaneously[46].

[46] This theory is similar to Lombard's (2000, cited in Van der Straaten, 2000) idea that presence occurs in an "instant-by-instant" manner (see section 2.1.1 of chapter 2 of this thesis).

2.1.5.1.3 Interaction Between Level 1 and Level 2 Factors of Spatial Presence

In agreement with other researchers in the field, the authors of the MEC-SPQ consider spatial presence to be a multidimensional construct. Vorderer et al. (2003) highlight the influence of media and user factors involved in the presence experience. The consistency of sensory cues, both temporally and across different sensory modalities, is important for presence to occur. If the sound of a driving car suddenly changes from that of a car to that of an airplane, the user is likely to be reminded of the mediate nature of the experience. Also, if a sound does not fit with what is visually present to the user, the user is likely to question the reality of his or her experience. The media-as-PEFR-hypothesis further assumes that the user's attention has to focus on the mediated stimuli in a continuous and consistent manner. Other media characteristics apart from the consistency of sensory cues, help to sustain attention to the virtual stimuli, including the "realness" of the stimuli presented, how meaningful the VE is to the user, and his or her interaction with it, the dramatic content of the medium and so on. Naturally, when the VE deviates from normal natural experience (such as in books and movies) the sense of presence also depends to a large extent on the user's ability and motivation to suspend disbelief. The main user characteristics influencing presence are involvement and motivation. These factors are further influenced by the user's mood and emotional state during the VE experience. Although closely linked, motivation and involvement can be thought of as separate constructs. While motivation is primarily a mental factor, involvement includes not only cognitive and affective factors, but also behavioural factors. The latter means that involvement also can be thought of as an action mode, a mode in which the user exhibits some sort of behaviour or action in the VE. Involvement with the VE indicates that the user is actively processing information received from the VE. The early stages of this process include many attentional resources. Although attention is continuously necessary for experiencing a sense of presence in the VE, later stages of involvement also include other processes such as problem solving and interest-oriented thinking. Further, user motivation influences the degree to which the user is able to suspend disbelief. Vorderer et al. (2003) defines suspension of disbelief as "the conscious and intended elimination of all external stimuli and internal ideas that might impede the spatial illusion" (p.24). This process is thought to be essential in stabilizing the tested media-as-

PEFR-hypothesis as it involves the suppression of stimuli arriving from competing PEFR hypotheses (i.e., in this case the physical world as PEFR). The authors believe this motivational factor to be related to the underlying trait of absorption.

2.1.5.2 Description of the MEC-SPQ

The development of the MEC-SPQ was based on the above theory of spatial presence, and the item analysis of the MEC-SPQ produced eight scales: Attention Allocation (AA), Spatial Situation Model (SSM), Spatial Presence (Self Location) (SPSL), and Spatial Presence (Possible Actions) (SPPA) are indicative of underlying process factors[47]. Higher Cognitive Involvement (HCI) and Suspension of Disbelief (SoD) are considered to refer to states[48] and actions. Domain Specific Interest (DSI), and Visual Spatial Imagery (VSI) are considered to refer to trait-like characteristics of the user. The two spatial presence scales, SPSL and SPPA, are considered to be the scales most reflective of the experience of a sense of presence in a VE. The remaining scales are considered to be underlying processes that influence the overall experience of presence in the VE. The questions on the MEC-SPQ are answered according to a 5-point Likert scale. Examples of questions include: "I devoted my whole attention to the VE"; "I had a precise idea of the spatial surroundings presented in the VE"; "I felt like the objects in the presentation surrounded me"; "I had the impression that I could be active in the environment of the presentation"; "I thought intensely about the meaning of the VE presentation"; "I directed my attention to possible errors or contradictions in the VE"; "I am generally interested in the topic of the VE"; and "It's easy for me to negotiate a space in my mind without actually being there".[49] All subscales[50] contain high internal consistency (Cronbach's alpha): AA, $r = .91$; SSM, $r = .87$; SPSL, $r = .92$; SPPA, $r = .86$; HCI, $r = .74$, SoD, $r = .86$; DSI, $r = .92$; and VSI, $r = .80$ (Vorderer et al., 2004). The questionnaire's high inter-scale correlations provide evidence of construct validity, which further support the underlying theory of the MEC SPQ (Böcking et al., 2004a; 2004b). Further, the MEC-SPQ

[47] Process factors here refer to characteristics of the VE experience that are necessary for the experience of spatial presence in a VE to occur.
[48] States here refer to characteristics of the individual that vary during the VE experience.
[49] See appendix B for the full 6-item version used in the study described in this thesis.
[50] The reliability measures cited refer to the 6-item version applied in the study described in this thesis.

has shown to be able to measure different intensities of the presence experience and is thus applicable to measure presence across different media/VEs (Böcking et al., 2004b).

2.1.6 Other Subjective Measures

A number of other questionnaires have been developed to measure presence. Some questionnaires measure both physical and social presence (e.g., the Lombard and Ditton Questionnaire, 2000, cited in Van Baren & IJsselsteijn, 2005; the Novak and Biocca Questionnaire, 2003, cited in Van Baren & IJsselsteijn, 2005) and some measure social presence only (e.g., Bailenson et al. Questionnaire, 2001; Basdogan et al. Questionnaire, 2000; IPO Social Presence Questionnaire, De Greef & IJsselsteijn, 2001 etc.). Other measures include IJsselsteijn et al's (1998) continuous presence measure in which the user continuously measure his or her sense of presence by adjusting a slider-button throughout the VE experience. In addition, such methods as cross-modality matching (CMM) (Welch, 1997) can be used. CMM procedures ask the user of the VE to relate the sense of presence experienced in the VE to some other sensory modality such as light or sound. For example, a user may be asked to adjust a particular sound according to the level of presence she experiences in the VE. This method can be particularly useful to measure constructs that are difficult to rate with verbal descriptions (IJsselsteijn, De Ridder, Freeman, & Avons, 2000). Further, paired comparison (Schloerb, 1995, cited in Van Baren & IJsselsteijn, 2005; Welch et al., 1996, cited in Van Baren & IJsselsteijn, 2005) involves asking VE users to compare the sense of presence experienced in different types of VEs and/or distinguish between a real world scene and one simulated by technology. Other measures include counting the number of times a user reports "breaks" in presence (i.e., transitions between the physical and the virtual environment) (Slater & Steed, 2000), attention and awareness measures (Darken, Bernatovich, Lawson, & Peterson, 1999), spatial memory measures (Darken et al., 1999), and spatial memory awareness states measures (Mania, Troscianko, Hawkes, & Chalmers, 2003). Qualitative measures such as content analysis (Rourke, Anderson, Garrison, & Archer, 1999), focus group exploration (Freeman & Avons, 2000), experience sampling method (ESM) (Gaggiolo, Bassi, & Della Fave, 2003), and interaction analysis (Spagnolli, Varotto, & Mantovani, 2003) are also used on occasion.

2.2 Behavioural Measures

Behavioural theories assume that users' unconscious behaviours while interacting with a VE, can indicate the level of presence experienced in the VE. In this view, the degree to which there is a match between behaviours while in the VE and those normally observable in the physical environment will provide an objective measure of presence. For example, if the user of a VE is driving a racing car, the degree to which they physically swing from one side to the other will be indicative of the level of presence experienced in the VE. Research examining movements of the physical body to different types[51] of VE interaction support this theory (Murray, Bowers, & West, 2000; Freeman, Avons, Pearson, & IJsselsteijn, 2000). Some researchers found have a link between presence and behavioural responses to stressful (virtual) stimuli such as the exposure to a steep virtual "cliff" (Meehan, 2001, cited in Insko, 2003; Insko, 2001, cited in Insko, 2003). The degree to which users exhibited responses to this stimulus that simulated responses associated with real dangers of the same type (e.g., taking small steps, leaning away from the "cliff", testing the edge with a foot etc.), was hypothesized to be indicative of the user's level of presence. Slater, Usoh, and Chrysanthou (1995) investigated presence by looking at the effects of presenting both virtual and real stimuli to the user at the same time. The users were shown a real radio located at a particular location in the room before entering the VE. A virtual radio was also situated at a location in the VE similar to that in the physical environment. During the VE exposure, the researchers moved the real radio and turned it on. Participants were then asked to point towards the radio. Presence was measured by the degree to which the user would point to the radio in the VE as opposed to the radio in the physical environment. Results of this study showed a significant correlation between this measure and subjective ratings of presence on a set of six

[51] Examples include turning the head to the sides when looking around in the VE or down when trying to look under objects in the VE, and postural response to driving a racing car from a FFP (use of magnetic tracking device to record changes in postural response) however, subjective presence ratings and postural response did not correlate across subjects in this study.

questions related to presence. Other types of behavioural measure include reaching for virtual objects, greeting avatars, turning away or closing ones eyes when presented with anxiety-provoking stimuli (Wiederhold, Davis, & Wiederhold, 1998, cited in Insko, 2003), startle responses (Held & Durlach, 1992), facial expression (Huang & Alessi, 1999), reflex responses (Nichols, Haldane, & Wilson, 2000, cited in Van Baren & IJsselsteijn, 2005), and social response[52] (Bailenson, Blascovich, Beall, & Loomis, 2003).

An additional group of behavioural measures have focused on performance in VEs. Studies of human performance in VEs have focused on cognitive, perceptual, and motor performances across a broad range of task and VE conditions. The VE conditions have varied in terms of display characteristics, number of sensory modalities, and other software variables. Examples include completion time and error rate (accuracy) (Basdogan et al., 2000), number of actions needed to complete a task (Slater, Linakis, & Kooper, 1996), and the degree to which skills learned in the VE transfer to real world situations (Youngblut & Perrin, 2002, cited in Van Baren & IJsselsteijn, 2005). Stanney, Mourant, and Kennedy (1998) argue that skills learned in a VE can be transferred to the physical environment. Together with the navigational complexity of the VE and the degree of presence experienced by the user, performance on benchmark tasks can tell us something about the overall performance of the user in the VE. Stanney et al. list a number of benchmark tasks including "the ability to move about in the VE (i.e., forward, backward, up, down etc.), manipulate or track virtual objects, locate virtual sounds, respond to kinaesthetic force feedback, perform visual tasks (i.e., perceive and discriminate colours; judge virtual distance; search for, recognize, and estimate the size of virtual objects)" (p. 330). They argue that higher-level skills such as navigational ability also should be included in batteries of such benchmarks tasks. According to these authors, performance in VEs is affected by task and user characteristics, as well as design constraints related to human sensory and motor physiology, integration issues with multimodal interaction (i.e., consistency of sensory stimuli), and the potential need for new visual, auditory and haptic design metaphors uniquely situated to VEs

[52] Bailenson et al. (2003) measured social responses by observing socially conditioned behaviours in reaction to social virtual encounters.

(i.e., such as the use of the Gibsonian term 'affordances' to provide opportunities for action in the VE).

Behavioural measures are, at best, indirect measures of someone's phenomenological experience of presence. However, they contain less subjective bias[53] than subjective measures, and they do not normally intrude into the virtual experience itself. On the other hand, a common problem encountered with the use of behavioural measures is experimental bias. Experimental bias[54], for example in the process of identifying and assigning qualities to the behavioural response of the user (Kaplan & Saccuzzo, 2001), may come into play. Different researchers may classify the same behaviour under different headings, and the researcher may sometimes steer his or her evaluation towards providing evidence that will support their initial hypotheses. In addition, it can sometimes be difficult to determine that the behaviour exhibited by the user was in fact produced by the VE and not by some other non-accounted for variable such as distractions coming from the physical environment. In situations where the VE is most likely to be producing the measured behaviour, it can be difficult to precisely identify what aspect of the VE is responsible for this. Sometimes a response can be caused by the VE system itself (e.g., by the volume of a sound), while other times it may be a result of the VE content (e.g., if hearing a big explosion as opposed to a whistle). Behavioural measures are also very unlikely to transfer across different VEs and different media. Further, the fact that behavioural measures often involve the scoring of post-immersive videotapes adds substantial time to the measurement process.

2.3 Physiological Measures

Similarly to behavioural measures, physiological measures are thought to measure unconscious user responses to a VE indicative of presence. Some measures often focus on cardiovascular factors such as heart rate and blood pressure. The underlying theory of these

[53] Subjective bias refers to the degree to which the information obtained from a measure is influenced by the participant(s) (e.g. preferences, understanding of questions etc) or researcher(s) (e.g. perception of measured behaviour, wording of questions etc.).

[54] Experimental bias refes to some condition of the measurement process other than the participant's own experience that influence the information obtained.

types of measures is that presence is affected by arousal (and that arousal is affected by presence) (Dillon, Keogh, Freeman, & Davidoff, 2000). Heart rate can be used as an indicator of emotional arousal and both high and low levels of heart rate can be associated with presence, depending on the content of the VE and type of interaction with the VE. Heart rate can be measured with an electrocardiogram (ECG) which records electrical activity on the skin associated with the individual's heart rate, or by recording electrodermal activity (EDA)[55] (Dillon et al., 2000). Also changes in temperature can be indicative of the level of arousal of the user (Insko, 2003). Other physiological measures include eye tracking and pupil response (Laarni, Ravaja, & Saari, 2003), EEG recordings of cortical activity, electromyogram measurements of facial muscle tension, respiration tare, and blood pressure (Insko, 2003).

Because presence and arousal are thought to be related to each other (Dillon, Keogh, Freeman, & Davidoff, 2000), Banos et al. (2004) investigated the effects of immersion and emotion on presence. They found that immersion only influenced the sense of presence through the degree of "negative effects"[56] produced by the different VEs. Emotional environments had a greater effect on presence than neutral environments. Interestingly, immersive VEs, such as those involving a head-mounted display or a big screen elicited a higher sense of presence than the less immersive systems, except when the less immersive systems involved emotional content. This study then supports the theory that presence is not a direct consequence of sensory immersion alone.

Physiological measures are more objective than subjective measures, and often more so also than behavioural measures. Additionally they are continuous measures and can therefore record changes over time. Meehan (2001, cited in Insko, 2003) showed that physiological measures (heart rate, skin temperature, and galvanic skin response) reliably discriminated between different experimental conditions (i.e., Mehaan varied such factors as frame, passive haptics, lag, visual field, interactivity and so on to create low, medium, and high presence conditions). They also seem to be relatively non-time consuming and do not interfere much

[55] EDA is a measure of the electrical activity between two points on the skin (i.e., skin conductance).
[56] Presence was here measured by the ITC-SOPQ which contains a negative effects factors.

with the VE experience (Insko, 2003). However, as with behavioural measures, it can sometimes be difficult to assess what causes the physiological responses. Numerous factors may be involved, including individual differences in physiological levels (i.e., even when great care is taken to standardize conditions across subjects, underlying individual differences may still confound the data obtained). This problem may be addressed partly by obtaining individual baseline measures prior to the experimental condition. In addition, equipment needed to perform such measures and the general procedures needed may add costs to the study.

2.4 Summary

Subjective presence measures have good face validity and often seem to be able to obtain some degree of information about the construct being measured. Behavioural and physiological presence measures are indirect measures that can be used to assist the measurement of presence when using subjective measures such as questionnaires. However, as subjective measures are often based on different conceptualizations of presence, there is a need for a unified definition and conceptualization of this construct. The MEC-SPQ attempts to do exactly this by basing itself on broader range of presence factors than those normally included in other measures. According to the MEC model, the perception of spatial cues from the VE and the construction of a spatial-situational model of the VE are necessary for the experience of spatial presence in a VE to occur. Thus, the following chapter will take a closer look at what spatial ability is, the ways in which such ability can be conceptualised in terms of a number of spatial ability sub-factors, and the way these abilities are affected by general cognitive processes. Further, the role of spatial ability in navigation, both in physical and virtual environments, is examined.

3 SPATIAL ABILITY

Most tasks that we encounter in everyday life involve some aspect of spatial ability. Walking, driving, opening doors, or tying one's shoelaces all involve spatial abilities that allow us to execute these movements in an efficient and smooth manner. To traverse the environment we need to have some sense of where objects are in the world and the relationship between them. We also need to have an understanding of distance, height, width, and depth. Spatial cognition plays an important role in human perception of 'space' and our sense of 'being in' and feeling present in an environment, whether it is either real or virtual. That is, spatial abilities aid the creation of a mental model of the surrounding space within which a sense of presence can be experienced. Such abilities also affect the speed and accuracy with which spatial cues from the environment are detected and the vividness of the visuo-spatial mental image created (Vorderer et al., 2003). Together with the spatial cues offered by the VE, spatial abilities also affect performance in real and virtual environments. Thus, the development of VE technology itself relies on, among other things, theories of spatial cognition in much the same way as the arts apply "tricks of illusion" to produce a sense of depth perception and space in paintings. The sophistication of VEs does not currently meet the full complexity of the physical world, nor may it ever. In this chapter I shall take a closer look at certain primary aspects of spatial cognition and ability. I will also look at gender differences on two spatial ability tasks in particular, mental rotation and object-location memory, and discuss the ways in which these abilities influence the experience of 'space' and navigation in real and virtual environments. Then, I will examine some specific aspects of the VE system itself that influence a user's level of presence in the VE through matching the spatial characteristics of the VE with human spatial cognition.

3.1 The Conceptualization of Spatial Ability

The psychological study of spatial ability originates in human intellectual ability research. In 1896, Binet together with Henri, suggested that human intelligence involves ten separate factors; memory, imagery, imagination, attention, suggestibility, comprehension, aesthetic appreciation, moral sentiment, motor skill, and judgment of visual space (Guilford, 1967, cited in Flynn, 1996). They were looking to measure a set of cognitive constructs that, in combination, would generate an overall estimation of an individual's intellectual ability[57]. Through the development of intelligence theories and the intelligence tests themselves, the identification and specification of theoretical, or cognitive, constructs emerged.

The term spatial ability was first introduced in the 1920s and 1930s when researchers started using factor analysis in the study of human intelligence. New measures of intelligence led to a further differentiation of the spatial ability construct into separate spatial ability factors. However, early attempts at identifying these factors were characterized by a lack of standardization of research procedures and overlapping factor labelling and descriptions. Different labels were assigned to factors that were given very similar definitions among researchers. Table 3.1 shows an overview of some of these early descriptions. Guilford and Lacey's (1947, cited in Flynn, 1996) *visualization* construct closely resembles what is today known as *mental rotation*. This construct indicates an ability to mentally manipulate and rotate objects, and is often found to be measured by such tests as the Vandenberg and Kuse Mental Rotation Test (Silverman & Eals, 1992). However, new data seem to indicate that the *spatial relations* construct also closely resembles mental rotation (Cornoldi & Vecchi, 2003). The theoretical differentiation of visualization (e.g., mental rotation) and spatial relations may therefore be somewhat arbitrary, and another term, such as *imagery manipulation ability* suggested by Cornoldi and Vecchi, may be considered more appropriate (see Table 2). However, the definitions of *spatial orientation* proposed by Michael, Zimmerman, and Guilford (1957, cited in Flynn, 1996) and French, Ekstrom, and Price (1963, cited in Flynn, 1996) have remained relatively consistent (see Table 3.1 and Table 3.2). McGee (1979, cited in Flynn, 1996) argues that spatial ability may be best defined by two main factors only: Spatial Visualization and Spatial Orientation[58]. Thurstone (1950, cited in Hegarty & Waller, 2004) argues that spatial visualisation tasks are characterised by object-based[59] spatial transformations. That is, an object is moved in relation to an outer environmental reference

[57] Binet later encapsulated his ideas into what is today known as the Binet Intelligence Scale.
[58] These are two of the most commonly used terms in today's literature on spatial ability.
[59] Frame of reference is centred on the object.

frame[60] while the person's egocentric reference frame[61] remains unchanged (e.g., rotating an object). In contrast, spatial orientation tasks are characterised by executing spatial transformations in relation to one's own egocentric frame of reference that is, while the egocentric frame of reference changes the relation between the object-based and environmental frames of reference remains unchanged (e.g., rotating one's own body around an object) (Thurstone, 1950, cited in Hegarty & Waller, 2004). However, Clements (1981, cited in Flynn, 1996) and Flynn (1996) contend this distinction to be unnatural due the two constructs' shared characteristics. They argue that spatial ability is better viewed as *one* factor. In this view, spatial ability may be thought of as a person's ability to contain complex spatial information in working memory, and mental rotation ability (i.e., spatial visualization) as also playing an important role in spatial orientation[62]. This involves imagery and often means holding a mental representation of the spatial information provided by the environment and/or brain (e.g., memory). This would mean that individual differences in spatial ability refer to the complexity of information that an individual can keep in working memory at any one time. Lohman (1979, cited in Flynn, 1996) supports a similar idea to that of Clements (1981, cited in Flynn, 1996) by suggesting that specific factors may be more appropriately discussed as sub-components of one overall spatial ability factor. This indicates that underlying perceptual and, in particular, *cognitive* processes involved in spatial ability may provide further refinement of the spatial ability construct.

Applying Logie's (1995, cited in Sala & Logie, 2002) visuo-spatial working memory (VSWM) model to describe spatial ability highlights these underlying cognitive processes of spatial ability (see Table 3.2 for an overview of spatial ability factors described within the framework). The VSWM was developed based on the working memory (WM) model proposed by Baddeley and Hitch in 1974 (cited in Baddeley & Hitch, 1994). The Baddely and Hitch model involved three main components: 1) the phonological loop, which deals with phonological and acoustic information as well as some visual information; 2) the visuo- spatial scratchpad, which deals

[60] The environment is itself the frame of reference.
[61] Frame of reference in centred on one's body.
[62] This issue will be dealt with later in this chapter, particularly in relation to the construction of a *complete* mental image (e.g., mental map) of one's (immediate) surrounding environment (i.e., from an egocentric frame of reference), movement, and characteristics of a VE such as field of view (FOV) and perspective (i.e., frame of reference).

Table 3.1[63] Early definitions of spatial abilities (see Appendix C for an amended version of this table)

Investigator	Factor Label	Factor Name	Factor Description	Tests
Guilford & Lacey (1947)	Vz	Visualisation	Ability to imagine the rotation of depicted objects, the folding or unfolding of flat patterns, the relative changes of position of objects in space	Vz: Pattern comprehension, mechanical comprehension
	SR	Spatial Relations	Relating different stimuli to different responses, arranged in spatial order	SR: Instrument comprehension, aerial orientation
Thurstine (1950)	S1		An ability to recognize the identity of an object when it is seen at different angles	S1: Flags, Card Rotation
	S2		An ability to visualize a configuration in which there is movement or displacement among the internal parts of the configuration	S2: Surface Development, Paper Puzzles
			An ability to think about those spatial relations in which the body orientation of the observer is an essential part of the problem	S3: Cube Comparisons
French (1951)	S	Space	Ability to perceive spatial patterns accurately and to compare them with each other	
	SO	Spatial Orientation	Ability to remain unconfused by the varying orientations in which a spatial pattern may be presented	
	V1		Ability to comprehend imaginary movement in three-dimensional space or the ability to manipulate objects in the imagination	
Michael, Zimmerman, & Guilford (1957)	SR-O	Spatial Relations and Orientation	Ability to comprehend the nature of the arrangement of elements within a visual stimulus pattern with respect to the examinee's body as a frame of reference	SR-O: Cubes, Flags, paper puzzles, aerial orientation
	Vz	Visualisation	Mental manipulation of a highly complex stimulus pattern	Vz: Form Board, directional plotting, pattern comprehension
French, Ekstrom, & Price (1963)	Vz	Visualisation	Ability to manipulate the stimulus and alter its image	Vz: Form Board, paperfolding, Surface
	S	Spatial Orientation	Perception of the position and configuration of objects in space with the observer as reference point	S: Card Rotations, Cube Comparisons

[63] This table is adapted from Flynn (1996, p.7).

with visual information from both perceptual and imagery processes; and 3) the central executive, which is composed of attentional processes thought to control both the phonological loop and the visuo-spatial sketchpad. In this model, working memory is seen as a short-term storage for information (i.e., from both the environment and long-term memory) and a "gateway" between perception and long-term memory (i.e., information is temporarily stored in working memory, rehearsed, and then transferred to long-term memory). Similarly, the VSWM model view WM as a "work space" where both perceived information and information stored in long-term memory is accessed simultaneously (Sala & Logie, 2002). However, recent research indicates that "WM is better viewed as a system accessed by information stored in long-term memory and by sensory input only after that input has been processed by long-term memory" (Sala & Logie, p. 825). This means that perceived information is directly linked to information stored in long-term memory without going through WM first. Further, research also suggests that separate processes are involved in visual and spatial cognition. Sala and Logie use the term *visual cache* to refer to the component responsible for the temporary retention of visual information such as static patterns and visual appearances, while *inner scribe* refers to the component involved in the retention of spatial information such as sequences of movement.

Neuropsychological research findings have shown that the primary visual cortex plays an important role in both the processing of visual information, and the generation of mental imagery (Baddeley & Hitch, 1994; Kosslyn, 1996). This suggests that mental imagery contributes, not only to the generation of mental images, but also to the process of visual perception per se. Kosslyn (1996), in his book *Image and Brain: The resolution of the imagery debate,* argues for an integrated theory of visual perception and mental imagery. In his view, imagery relies on topographically[64] organized regions of the cortex that support depictive mental representations (i.e., image representations that contain spatial properties). Visual memory[65] works as a pattern activation subsystem that, combined with imagery processes[66] allows us to generate fully three-dimensional representations of partially visible

[64] Topography refers to the configuration of a surface and the relations among its features.
[65] Visual memory refers to stored visual information about objects previously perceived from different angles or vantage points.
[66] Imagery processes refers to the "imagining" of stored visual information elicited by visual memory.

as well as novel objects perceived in one's immediate environment. As such, imagery works as "glue" between visual memory pattern activation and perception to create a complete mental image of what is being perceived. This process of pattern activation involves a number of sub-systems (e.g., coordinate and categorical spatial relations encoding, associative memory, attention shifting, shape shift etc.) that continuously update the mental image, or representation. Thus, we use imagery to help identify objects in the world and to create mental representations of that which is being perceived. This theory supports the assumption made by the VSWM model of a direct link between perceived stimuli and information stored in long-term memory (i.e., stored patterns of information).

Studies have also shown that mental representations can be generated solely from memory (i.e., mnestic representation) (Cornoldi & Vecchi, 2003). Cornoldi and Vecchi refer to the difference between "what we imagine" and "what we see" as the *generated image* and the *visual trace image* respectively. The generated image relies on high levels of attentional processes and information stored in long-term memory. The visual trace image, on the other hand, utilizes very low levels of attentive processes and does not acquire much information from long-term memory, as these images are largely products of sensory received information. Mental imagery may also be influenced by other sensory sources such as hearing and smell, as well as by semantic systems (Cornoldi & Vecchi). Further, research into the similarities and differences between the generated image and the visual trace image has provided some interesting findings. Farah (1984, cited in Cornoldi & Vecchi, 2003) suggests that there exist two different neural pathways in the brain involved in the production of the generated image: the "what" and "where" neural pathways. She argues that these pathways indicate two separate processes: a visual pathway responsible for recognizing objects and understanding what they are (the ventral stream), and a spatial pathway for analyzing where an object is (the dorsal stream). These findings are also congruent with the separation of visual and spatial processes in the VSWM model and individual differences in these processes may occur.

Table 3.2[67] Some fundamental visuo-spatial abilities. (see Appendix C for an amended version of this table)

Ability	Description	Tests/measuring instruments
Visual organization	The ability to organize incomplete, not perfectly visible or fragmented patterns	Street Completion Test (Stree, 1931), Embedded Figures test (Witkin, Oltman, Raskin, & Karp, 1971), Hooper Visual Organisation test (Hooper, 1958), WAIS Object Assembly (Wechsler, 1944)
Planned visual scanning	The ability to scan a visual configuration rapidly and efficiently to reach a particular goal	Elithorn's Perceptual Maze test (Elithorn, Jones, Kerr & Lee, 1964), Trail-making test (Spreen & Strauss, 1991)
Spatial orientation	The ability to perceive and recall a particular spatial orientation or be able to orient oneself generally in space	Judgement of Line Orientation (Benton, Hamsher, Varney & Spreen, 1983)
Visual reconstructive ability	The ability to reconstruct a pattern (by drawing or using elements provided) on the basis of a given model	Koh's Blocks (see Block Design in the WAIS and WISC tests; Wechsler, 1945), Bender Gestalt test (Bender, 1938), Benton Visual Retention test (Benton, 1960), Complex Figure test (Rey, 1941)
Imagery generation ability	The ability to generate vivid visuo-spatial mental images quickly	VVIQ (Marks, 1972)
Imagery manipulation ability	The ability to manipulate a visuo-spatial mental image in order to transform or evaluate it	Mental Rotation test (Vandenberg & Kuse, 1978), Spatial Subtest of DAT (Bennett, Seahorse & Wesmann, 1954)
Spatial sequential short-term memory	The ability to remember a sequence of different locations	Corsi test (Milner, 1971), Tomal Subtests (Reynolds & Bigler, 1996)
Visuo-spatial simultaneous short-term memory	The ability to remember different locations presented simultaneously	Visual Pattern test (Della, Sala, Grey, Baddeley & Wilson, 1997)
Visual memory	The ability to remember visual information	Contribution of memory in the Complex Figure test (Rey, 1941)
Long-term spatial memory	The ability to maintain spatial information over long periods of time	Spatial Labyrinth (Milner, 1971)

VVIQ = Vividness of Visual Imagery Questionnaire

DAT = Differential Aptitude Test

[67] This table is adapted from Cornoldi & Vecchi (2003, p.16).

3.1.1 Navigation: Landmark, Route, and Survey Knowledge

Darken and Peterson (2001) define *navigation* as the "aggregate task of way-finding and motion" where way-finding refers to the "cognitive element of navigation" and motion to the "motoric element of navigation" (p. 1). Navigation is therefore inherently cognitive in nature as it is based on the acquisition of knowledge about the environment and where one is situated in that environment at any one time. Nash, Edwards, Thompson, & Barfield (2000) conceptualize spatial ability along three dimensions hypothesized to affect navigation in real as well as virtual environments: spatial orientation (ability to mentally transform or manipulate objects); spatial visualization (manipulation of the relations with an object); and spatial relations (ability to imagine the alignment of an object from different perspectives) (p.16 & 19)[68]. The navigational complexity of an environment, or how difficult it is to navigate through it, depends on the sensory cues provided by the environment, available navigational or spatial tools such as maps, as well as on the spatial ability of the user (Stanney et al., 1998). Navigational complexity is likely to vary across different media and within a particular *virtual* environment. Chance, Gaunet, Ball, and Loomis (1998) found that travel techniques influence the degree to which a person successfully navigates through a VE. In addition, their study showed a difference in users' sense of orientation between a head mounted display (HMD) condition most similar to 'real' walking (i.e., 'walk mode') and a condition involving a joystick to control heading and direction (i.e., 'visual turn'). The walk mode showed a stronger positive correlation with orientation in the VE than the visual mode. This result indicates that the body and head tracking devices used in the HMD condition may positively influence orientation in a VE.

The process of exploring and becoming familiar with a spatial environment, either real or virtual, involves the acquisition of different levels of knowledge about the environment. According to Thorndyke (1980, cited in Nash et al., 2000), these levels of knowledge can be divided into: landmark knowledge; path knowledge; and survey knowledge. First, landmark knowledge is a type of declarative knowledge and thus involves knowledge about facts and things (Colle & Reid, 1998). It includes knowledge about the particular characteristics of an

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[68] See section 3.1 for a discussion of these terms.

environment such as its landmarks or objects (e.g., trees, mountains, houses, cars etc.). Such landmarks help the individual to organize and remember information - they provide specific information about the environment that can be stored in the individual's memory. Thus, landmark knowledge also aids orientation. Landmark knowledge can be assessed by landmark recognition, landmark recall, and location recognition (Nash et al., 2000, p. 17). Second, route knowledge is a form of procedural knowledge that guides the application of cognitive strategies and rules for manipulating declarative, or landmark, knowledge (McCreary, 1997). Route knowledge is organized according to the topological[69] and metric[70] properties of the environment and is obtained when landmarks are used to identify and follow a path through an environment. This knowledge is centred 'around' the person and where that person has travelled, and includes the memorisation of observed landmarks. Route knowledge can be assessed through directional pointing tasks, route distance estimation tasks, route replication tasks, location sequencing, and orienting performance (Nash et al., 2000, p. 17). Last, survey knowledge is the type of knowledge acquired when multiple landmarks and multiple routes are combined to produce a mental, or cognitive, map of an environment. This type of knowledge is organized according to Euclidean[71] properties (i.e., knowledge about the dimensions of a space according to geometrically based coordinates). From a navigational perspective, such coordinates are commonly referred to as 'north, south, east, and west' coordinates. Thus, survey knowledge is the most advanced type of navigational knowledge and involves a view of the environment centred 'outside' the person. In the case of VEs, this information is also centred outside the boundaries of the VE (i.e., the virtual space is viewed, similarly to real space, as consisting of a number of spatial dimensions). The measurement of survey knowledge involves pointing tasks, Euclidean distance estimation tasks, search effectiveness, alternate route selection, object placement tasks, and map drawing (Nash et al., 2000, p.17).

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[69] Topological properties refer to the configuration of a surface and the relations among its man-made and natural features as they are perceived by the individual.

[70] Metric properties refer to the function of a topological space that gives, for any two points in the space, a value equal to the distance between them (e.g., the mathematical or "Newtonian" characteristics of the space as measured by a metric system based on the meter, the kilogram, and the second).

[71] The term 'Euclidean' relates to the geometric theorems proposed by Euclid to describe plane and solid surfaces. A Euclidean 'space' refers to a two- or three-dimensional space in which the axioms and postulates of Euclidean geometry apply. It is also a space in any finite number of dimensions in which points are designated by coordinates (one for each dimension) and the distance between two points is given by a distance formula (Oxford English Dictionary, 2000).

The landmark-route-survey (LRS) model has been criticized for its simplicity and restrictive structure. Colle and Reid (1998) report a number of findings which indicate that people are able to acquire survey knowledge about the environment more rapidly than the LRS model would suggest, and that such knowledge can be used during early stages of navigation in complex environments. To further conceptualize these findings, these authors suggest two modes to describe the early stages of spatial exploration: 1) the gaze view mode; and 2) the route tour mode. These modes can occur separately or in conjunction, and do not necessarily operate in sequence. The first mode is characterized by obtaining information from the environment that is within the user's immediate spatial field of view (FOV)[72] (i.e., "within their spatial span of attention", p. 118): "Gaze view representations are obtained perceptually when an individual rotates his or her head or body" (p. 118). These representations can therefore be thought of as exploring one's immediate surroundings in all directions from a first person perspective (FPP)[73]. The gaze view mode can be used to imagine the immediate visual scene from different vantage points within that scene. Thus, according to this theory, the skills used to orient oneself within one's immediate visual environment also involve survey knowledge to a certain degree by creating an overall mental map of one's immediate surroundings as perceived from a FPP. The ability to do this involves imagining the rotation of one's body or head and thereby also the features of the environment so that the mental representation results in a complete three-dimensional map of one's immediate surroundings. In contrast, the route tour mode involves the use of topological information about the environment to find one's way from one point to the other in an environment (e.g., remembering landmarks to help orient oneself with regards to areas of the environment not currently in one's immediate field of view). Thus, this mode identifies characteristics of the larger environment including areas outside the person's immediate spatial attention. Nash et al. suggest that survey knowledge about the larger environment, including areas not in the immediate FOV, may be produced by combining the already obtained metric information within small scale areas into one coherent large scale environment. That is, mental maps that are continuously created of one's immediate spatial surroundings as one traverse an

[72] I will discuss the role of field of view (FOV) for navigation in VEs more thoroughly later in this chapter.
[73] First person perspective in VEs will be discussed more thoroughly later in this chapter.

environment are combined into one overall map of the larger, extended, environment. However, a study conducted by Colle and Reid (1998) on navigation in VEs showed that, although people quickly acquire metric information about their immediate environment, only topological information about the location of specific small scale areas (e.g., in this case the location of rooms) was available when starting to traverse a VE.

To conclude, the literature on spatial ability and navigation indicate that specific abilities can be identified within one overall spatial ability construct. Further, such abilities influence navigation in an environment. One way of investigating such spatial abilities in more detail has been to look at possible individual differences in these abilities. A common approach to such research involves the investigation of gender differences in performance on specific spatial ability tasks. The next section will take a closer look at literature derived from this area.

3.2 Gender Differences in Spatial Ability and Navigation

Research has shown robust and reliable sex differences in spatial ability. Three sets of abilities have received particular attention in this context: mental rotation, object-location memory, and navigation abilities. Research shows that men tend to be better than women at manipulating and rotating mental images, as well as reading maps and navigating an environment by the means of finding paths (Silverman & Eals, 1992; Kimura, 1993, 1999). Galea and Kimura (1993) argue that there exist a relationship between mental rotation ability and the use of maps (i.e., survey knowledge) for navigation[74]. Other researchers have also shown a significantly positive correlation between mental rotation ability and navigational ability (Moffat, Hampson, & Hatzipantelis, 1998, cited in Ecuyer & Robert, 2004; Silverman et al., 2000). On the other hand, females tend to be better than males at remembering objects, including landmarks, and their specific location in the environment (Silverman & Eals, 1992; Kimura, 1993, 1999; Choi & Silverman, 2003). Females more commonly apply navigational strategies related to landmark and route knowledge to navigate an environment, while males

[74] See section 3.2.2 for a description of their findings.

more commonly apply survey knowledge (Choi & Silverman, 2003; Ecuyer-Dab & Robert, 2004). Choi and Silverman (2003) suggest that gender differences in underlying spatial processes may lead individuals to attend to differential environmental cues, which may, in turn, produce different route-learning strategies. Thus, gender differences are affected by strategy use, stimuli complexity and processing speed among other things. Several meta-analytic studies have found evidence to support these findings (Devlin, 2001).

A common male strategy in maze solving tasks is to create a mental map (i.e., survey knowledge) of the maze (Choi & Silverman, 2003; Ecuyer-Dab & Robert, 2004). This mental map is continuously updated to fit the person's changing position in the maze. When a person looks or walks in a new direction the mental map must be adjusted, or rotated, accordingly. Thus, navigating a maze by the means of a mental map involves a strong ability to hold complex spatial information in working memory and to produce a vivid mental image from this information. In contrast, females tend to navigate a maze by focusing on specific features of the surrounding environment such as objects, colours, shapes and so on (Choi & Silverman, 2003). Thus, females tend to be more dependent on memorising and recognising objects than mental image creation for navigation.

Mental rotation tasks are examples of tasks that involve the ability to hold complex spatial information in working memory in terms of a mental image, and can also be associated with the use of mental maps involved in the 'gaze view' mode of navigation proposed by Colle and Reid (1998). Birenbaum, Kelly, and Levi-Keren (1994, cited in Devlin, 2001) list three stages of processing in mental rotation tasks: 1) stimulus search (i.e., "examining the stimulus for features to consider in the rotation"); 2) initial rotation (i.e., "the first rotation made of the stimulus"); and 3) confirmation ("checking to see that other features of the stimulus are also properly rotated") (p. 52). They found that females take longer time than males to complete the confirmation stage. Further, Bryden, George, and Inch (1990) propose that although males and females apply the same strategies in mental rotation tasks, females tend to spend more time in applying these strategies than do males. Tanaka, Panter, and Winborne (1988, cited in Devlin, 2001, p.49) argue that females tend to have a preference for dealing with information in a multidimensional[75] manner that is, "a preference toward evaluating and processing all aspects of the given information deliberately and completely". Blough and Slavin (1987, cited in Devlin, 2001) similarly argue that while men more often apply a holistic[76] strategy when solving these problems, women have a bias towards using an analytic strategy[77] as they are more concerned about the accuracy of their performance. This is, for example, reflected in men's tendency to use mental maps and Euclidean coordinates to guide navigation, and females' tendency to focus on specific aspects of the spatial environment such as objects and landmarks to aid this process. These findings indicate that females tend to apply an analytical, deliberate, and exhaustive approach to solving mental rotation tasks (Devlin, 2001).

3.2.1 Biological Perspectives

Brain lateralization has been extensively investigated in neuropsychological research. While the right side of the brain has been ascribed to serve a main function in solving holistic and spatial problems such as mental rotation tasks, the left side of the brain seems to deal more generally with verbal information and operate in more analytic terms (Kosslyn & Rosenberg, 2001). The research findings discussed in the previous section indicate that the male and female brains may utilise these brain functions somewhat differently when solving spatial tasks.

Females tend to outperform males on a number of verbal tasks such as verbal fluency (Silverman & Eals, 1992). Thus, females may be more biased to utilize these verbal and analytical abilities also when solving spatial problems. A study conducted by Silverman and Eals (1992) supports earlier findings where males perform better than females on mental

[75] Multidimensional manner refers to investigating multiple aspects of the information provided both separately and in combination (e.g., analytic approach). This is done consciously and specific.
[76] A holistic strategy refers to dealing with information by looking at the overall combinations, or patterns, of information rather than its individual components, or units.
[77] An analytic strategy refers to approaching information by dividing it up into separate units of information and investigates these both individually and in combination (i.e., multidimensional approach).

rotation tasks. However, they also found that females tend to perform better than men on two other spatial ability tasks, namely object memory and object-location memory[78]. Silverman and Eals hypothesized that females' enhanced verbal ability may influence their performance on object memory tasks by memorizing object names rather than their distinctive features (i.e., by applying more verbal strategies, or left hemisphere-related abilities). Further, regional cerebral blood flow in the brain during spatial ability tasks indicate that people utilizing the right hemisphere systems in solving spatial tasks perform better than people with a more bilateral approach (Devlin, 2001). Some studies have attempted to find evidence of a biological difference in the level of asymmetry between the genders however, evidence both confirming and disconfirming this hypothesis has been observed (Kimura, 1993).

Underlying biological mechanisms have become a popular topic for explaining some of the gender differences observed on spatial ability tasks. Sex hormones, especially androgens, affect the development and the organisation of the brain in males and females (Kimura, 1999). Research has shown that females who have been exposed to androgens in prenatal or neonatal stages tend not only to become more "tomboyish" and aggressive than their female counterparts, but they also exhibit increased ability on spatial ability tasks (Kimura, 1993). However, the relationship between androgens and spatial ability does not seem to follow a linear relationship. Rather, there seems to be a threshold for an optimum level of androgen for spatial task performance. In a study including both males and females with exposure to different levels of androgens in their early biological development, females with a high level of androgens performed better than females with a low level of androgens, while males with a high level of androgens performed *worse* than males with a low level of androgens. In addition, the high-estrogen phases (midluteal and preovulatory) of the menstrual cycle has been associated with lower spatial ability than normal in females, and males seems to perform poorer on spatial ability tasks during the spring when their testosterone-levels increase (Kimura, 1993). Silverman and Eals (1992) found that the female bias in location memory ability increases at puberty when "female" hormones (e.g., estrogen, progesterone) are at its increase in concentration. However, the female bias in object memory, although

[78] It is important to note that research on object-location memory has found varied results regarding a sex difference on this task (e.g., Alexander, Packard, & Peterson, 2002; Postma, Izendoorn, & De Haan, 1998, etc.).

suggesting an overall bias towards female superiority, did not increase with puberty in their study. A tentative hypothesis to explain these findings could be that object memory is more strongly associated with the use of verbal or analytic processes (i.e., remember objects through verbal rehearsal) while location memory may be more associated with a subsequent improvement of navigational skills following puberty (Kimura, 1993). Kimura (1993) also reports findings on individual differences in the brain that supports a hormonal influence on spatial ability. These studies focus on the role of the hypothalamus in producing sex hormones and have found that the size of the suprachiasmatic nucleus of the hypothalamus varies between the sexes, as well as between heterosexual and homosexual men. The suprachiasmatic nucleus has been found to be larger in men than in women, and larger in heterosexual men than homosexual men. It turns out that not only do men perform better than women on spatial ability tasks, but heterosexual men also seem to outperform homosexual men on these tasks (Kimura, 1996).

3.2.2 Evolutionary Perspectives

Gender differences in spatial ability have been observed across human cultures, which indicate that they may well be universal human characteristics. Evolutionary perspectives have been proposed to explain some of these observations. Gaulin and Fitzgerald (1986, cited in Silverman & Eals, 1992) compared polygynous[79] and monogamous[80] wolves, and observed a male bias in spatial ability in the first that was not noticeable in the latter. They argue that males of polygynous species (including humans) will develop increased spatial abilities (compared to monogamous species) as a result of the need to navigate through a larger home range in their attempt to find potential mates and/or resources to attract mates. In contrast, Greenwood (1983, cited in Silverman & Eals, 1992) suggests that the crucial factor in the development of navigational abilities is "the distance an animal travels from its natal site to its first breeding place" (Silverman & Eals, 1992, p. 533). In his view, the most important factor in the mating system is the differentiation between resource defence and

[79] Polygynous refers to male animal species that have more than one female mate.
[80] Monogamous refers to animals that have only one mate.

mate defence mechanisms. He argues that in resource defence systems females will disperse more than males as the male would stay in his territory to protect the resource[81]. On the other hand, in mate defence systems, males will disperse more than females as a result of trying to locate and defend females. Gender biases in spatial ability would therefore follow these patterns. Greenwood (1983, cited in Silverman & Eals, 1992) suggests that mammals mainly employ a mate defence system and it would therefore be natural to observe a male bias for increased spatial ability among these species, including humans.

However, it would be difficult to predict an accurate gender difference in human spatial ability from these two perspectives as humans are not always polygynous and resource defence is an important issue, in particular for human females. A third evolutionary perspective proposed by Silverman and Eals (1992) focuses less on theories that can be applied across species and more on a particular aspect of human evolution, namely the hominid evolutionary period. These researchers argue that the division of labour between hunting and gathering in the early evolutionary stages of the human species influenced the development of different types of spatial skills among the genders. Hunting, which was a task mainly performed by males, required an ability to "orient oneself in relation to objects or places (in view or conceptualized across distances), and perform mental transformations necessary to maintain accurate orientations during movement" (Silverman & Eals, 1992, p. 534-535). This includes long-distance navigation and the ability to accurately follow the rotation of a target during hunting, and to throw projectiles with high precision. On the other hand, skills needed to gather food (e.g., berries) and other resources, a task primarily performed by females, included "recognition and recall of spatial configurations of objects; that is, the capacity to rapidly learn and remember the contents of objects arrays and the spatial relationships of the objects to one another" (p. 535). This would also have included the ability to detect small changes around the home (e.g., detect predators) and locate landmarks that would help females locate and remember the location of resources in their environment. In a study examining incidental learning of object-and location memory, Silverman and Eals's (1992) found that females tend to be naturally more alert to objects and their locations in the environment than males.

[81] The 'resource' here refers to the female.

A third theory suggests that gender differences in spatial ability have had more to do with human reproduction and survival than the division of labour. According to this theory, females' chance for successful reproduction is increased by reduced mobility during pregnancy. This has led females to be less exposed to long-distance navigation and subsequent need for long-distance navigation skills (Jones, Braithwaite, & Healy, 2003; Ecuyer-Dab & Robert, 2004). Further, male-to-male competition over available mates involves the searching for and protection of territory, as well as hand-to-hand combat. While searching for and protecting mates involves long-distance travel and navigation, hand-to-hand combat involves an ability to keep a mental image of a rotating figure (e.g., the enemy) in working memory. As previously mentioned, research has shown a significantly positive correlation between mental rotation ability and navigational ability (Moffat, Hampson, & Hatzipantelis, 1998, cited in Ecuyer & Robert, 2004; Silverman et al., 2000). Further, performance on a mental rotation task under timed conditions has been linked to the speed with which people are able to learn the correct route of a maze from a map (people performing well on the mental rotation task took the shortest time to learn the route) (Galea & Kimura, 1993). This suggests that the speed with which people complete mental rotation tasks can provide a time advantage in the processing of navigation-related information. In addition, applying a survey strategy for navigation (as men prefer to do) fits particularly well with the skill of rotating self-referenced spatial data as this is necessary when using mental maps (i.e., the person must hold and rotate the map, or spatial information, as he or she turns around and change directions), or when applying Colle and Reid's (1998) 'gaze view mode' for navigation. Thus, it may be possible that mental rotation ability originally evolved to directly support navigation, especially in men (Ecuyer-Dab & Robert, 2004).

3.3 Spatial Behaviour in Virtual Environments

Kozak, Hancock, Arthur, and Chrysler (1993) found evidence to support the hypothesis that spatial knowledge acquisition in VEs, as acquired through navigation, is similar to what takes place during navigation in the physical environment. Similarly, Witmer, Bailey, Knerr, and

Parsons (1996) found that VEs that adequately represent real world environments can be used to train route knowledge that is transferable from the VE to real world settings. The spatial ability of the user relative to the spatial demands of the VE influence the ease with which a user is able to navigate a VE. The use of VEs to train spatial skills has been proven to be an effective method. However, some evidence show that VEs are more effective when training men than when training women (Waller, Hunt, & Knapp, 1998). In a study investigating the transfer of spatial knowledge learned in a VE to the physical world, Waller, Hunt, and Knapp (1998) found that women performed significantly worse than men in the VE. In addition, women trained in the VE performed significantly worse than women trained in the physical world, while there was no gender difference in performance between men and women trained in the physical world. Further, a positive relation between performance and presence in VEs has been observed (Witmer & Singer, 1998; Youngblut & Huie, 2003).

Specific system characteristics can be applied to enhance the user's experience of space, and presence, in a VE and increase the likelihood for successful spatial ability training. One example of this is the use of stereoscopic displays. While monoscopic displays present one visual scene to both eyes and binocular displays present the same visual scene to each eye individually, stereoscopic displays present a slightly different version of the same visual scene to each eye. This use of two slightly differently displayed visual scenes produces an illusion of depth in the user as both scenes are integrated within their perceptual system. Such displays have been shown to have a positive effect on people's performance in VEs (Barfield, Hendrix, & Bystrom, 1999; McWorther, Hodges, & Rodriguez, 1991, cited in Nash et al., 2000). Although stereoscopic displays do not produce an accurate simulation of "real depth", they do so more than monoscopic or binocular displays. Stereoscopic displays are therefore also likely to influence the user's sense of presence in the VE, as increased depth perception enhances the sense of being situated within a three-dimensional space. Two other system factors particularly relate to spatial ability and the experience of a sense of presence in VEs, namely changes in field of view (FOV), and first-person versus third-person perspectives.

3.3.1 Field of View

The field of view (FOV) offered by visual displays (e.g., movies, TV, digital games, VR simulators etc.), in association with the visual system, "refers to the visual angle[82] (horizontal and vertical) subtended at the retina by an object in the environment" (Nash et al., 2000, p. 5). With regard to graphic displays, FOVs can be described through their geometric properties. The geometric field of view (GFOV) of a graphic display refers to the angle of an object when viewed from the centre of the projection or presentation. Changes in the FOV create a similar experience to that of using a zoom lens and the properties of different FOVs vary in size and degree (i.e., angle of viewed objects in the environment). Research has found that small FOV settings (compared to large FOVs) can produce increased search and movement times in VEs (Nash et al., 2000). This is because users will spend more time turning their head to view objects not located within their immediate FOV. When the size and angle of the FOV is larger, time is reduced as the user has immediate visual access to a larger proportion of the surrounding environment and can integrate larger amounts of the spatial information at a higher speed.

In a study examining children's and adults' experiences of VEs, McCreary (1997) found that both age and FOV size, as well as gender, influence performance in VEs. Her study showed that while there was little influence of these variables on obtaining landmark knowledge of the VE, overall spatial performance[83] increased with both age and FOV size. Small FOVs resulted in lower levels of spatial performance in both children and adults. A significant gender difference was observed on measures of survey knowledge, where males clearly outperformed females, especially among the adults (children had low performance on this task overall). Further, males spent less time than females constructing a model (i.e., a

[82] Visual angle refers to the position of the visually available information, or objects, as they exist in relation to the individual's FOV/retina. For example, imagine changing the FOV in your camera from normal view to a zoom view. After having zoomed in on an object of interest the angle from which that object is being perceived has become larger. Similarly, a first person perspective (FPP) FOV will have a smaller FOV (i.e., you can see less objects) than a third person perspective (TPP) FOV. Thus, objects within a FPP are 'larger on the retina' than objects in a TPP. Thus objects seen from a FPP have a larger visual angle than objects seen from a TPP(for a further description of FPP vs. TPP views see section 3.3.2).

[83] McCreary measured spatial performance by locomotion efficacy, landmark knowledge, route knowledge, and configuration knowledge. Please see her full thesis (McCreary, 1997) for details regarding these measurement procedures.

"drawing") of the virtual space. Interestingly, while men showed the expected increase in performance compared to boys on this task, women performed at the same level as the younger girls. McCreary notes that women tended to spend much time verbalizing what they remembered from the VE while the younger girls preferred to quickly immerse themselves in doing the task. This finding lends support to the theory that females, especially adults, tend to use more verbal and analytic strategies for solving spatial tasks than men.

3.3.2 First-Person versus Third-Person Perspectives

While reading books, watching movies, and playing digital games the FOV from which the VE is experienced often varies between an egocentric and an exocentric FOV. An *egocentric* FOV indicates that the person is imagining and experiencing the VE from a first-person perspective (FPP). An *exocentric* FOV means that the person is experiencing the VE from a third-person perspective (TPP). Users navigating computer-generated VEs can often choose between a FPP and a TPP (especially in the case of desktop environments). In a TPP an avatar[84] is often visible to the user (they can see their 'virtual body' in front of them). When changing between a TPP and a FPP the user changes their visual FOV from behind the avatar to 'inside the avatar's head'. Consequently, a TPP will have a larger FOV than a FPP. The user experiences a TPP as "seeing himself from the outside as an external observer standing back with respect to the visual scene with a larger field of view available onto the environment" (Amorim, Trumbore, & Chogyen, 2000, p. 166). Although larger FOVs can increase performance on certain spatial tasks in VEs (McCreary, 1997), the same positive correlation seems not to hold for the experience of presence. Rather, a FPP is thought to be more strongly correlated with high levels of presence than a TPP, as a FPP more accurately simulates natural, or real, experience (Lombard & Ditton, 1997). Navigating through a VE from a TPP is more like a "gaze tour" where the user obtains information about the VE by shifting their attention from the avatar to their surrounding environment (Amorim, et al., 2000, p. 166). The information given in this situation provides the basis for developing a mental model of the environment that can be incorporated into a holistic image of the VE

[84] Avatar refers to the visual representation of the user, or his or her "character".

within the user's imagination. In contrast, a FPP demands the user to mentally reconstruct and imagine the missing scene that would be viewed if they were actually rotating their virtual body (Kosslyn, 1990). The 'gaze view mode' hypothesis also supports this theory. This difference in FOV between FPP and TPP means that a FPP is likely to put larger demands on the user's ability to hold complex spatial information in working memory and their mental rotation ability than a TPP. The demands of speed and accuracy of this process are further increased as the user starts to travel through the VE and their mental model of the surrounding environment requires continuous updating of information according to his or her changing position or vantage point. From a TPP the position of the virtual body is visually available and the user has visual information readily available for them to infer what the scene would look like from different vantage points within their FOV. Amorim et al. (2000) argue that these different processes correspond to what Kosslyn (1980; 1987, cited in Amorim et al., 2000) has called the *shifts transformations* versus *blink transformations* on mental images. A TPP, like shift transformations, involves altering an already visually present image, while a FPP, like blink transformations, involves the fading out of one image for then to access stored patterns of spatial information and create a new image (p.181)[85]. That is, from a TPP, the visually available information is *adjusted* according to the user change of position within the VE, while from a FPP, visually available information is continuously *replaced* by new visually available information as the user change position and moves his or her head within the VE. Similar to Kosslyn (2001), Amorim et al. (2000) suggest that "it is the interplay of the content of the perceptual input and mental imagery-mediated memory processes that contributes to spatial updating and cognitive repositioning" (p. 183). Amorim et al. (2000) found that users travelling through a VE from a FPP updated the changing spatial environment (as seen from new vantage points) by associating it with the movements of their virtual body. The feeling of having a virtual body in FPP VEs can thus be considered a consequence of both the FOV (i.e., it is similar to 'real world' FOV and is therefore associable with embodying a physical body in the 'real world') and movement. Moving the virtual body while interacting with the VE from a FPP helped the participants to keep an accurate sense of their surroundings. However, no such movement was necessary to

[85] See section 3.1 for a description of the roles of stored spatial knowledge and imagery in Kosslyn's theory of visual perception.

be able to imagine new vantage points from a TPP. Thus, navigating a VE from a FPP seems to be facilitated by the user's experience of having, and moving, a virtual body. This experience of having a virtual body anchors users within the VE and is therefore likely to influence their sense of presence experienced in the VE.

3.4 Summary and Hypotheses

Recent research on spatial cognition and ability indicates that a multitude of sub-systems and underlying cognitive processes influence visual perception and mental imagery. The VSWM model examines such underlying factors in an attempt to describe different aspects of spatial ability and is supported by Kosslyn's (1996) theory of visual perception and imagery. Further, research has revealed that different areas of the brain are involved in different cognitive processes: a mental image can be created both from memory alone and in conjunction with perceptual processes, and different areas of the brain seem to be involved in distinguishing "what" an object is and "where" that object is located in the environment. Although some argue that spatial ability is best viewed as an overall ability to hold complex spatial information in working memory, these neuropsychological findings suggest that individual differences in the utilisation of these underlying processes may lead to individual differences on specific spatial ability tasks. Research on gender differences in spatial ability supports this theory. While men seem to be better than females at mental rotation tasks and navigating large-scale environments, females seem to be better than males at recognising objects in the environment and remembering their location. The acquisition of survey knowledge, or mental maps, is particularly important for males in navigation tasks (Choi & Silverman, 2003). Further, research suggests that mental rotation ability facilitates the use of maps for navigation (Galea & Kimura, 1993). The 'gaze view mode' (Colle & Reid, 1998) adds additional support to this relationship by suggesting that an individual continuously creates mental maps of their immediate surroundings by imagining, and mentally rotating, the immediate visual scene from different vantage points within that scene. Thus, mental rotation ability seems to be particularly important when navigating a VE from a first-person perspective (FPP), as its role in creating a complete mental map of one's immediate surroundings is essential (Colle & Reid, 1998). The stability of this mental representation aids the experience of a fully surrounding 'space' in which the person can feel present. This theory is congruent with Vorderer et al.'s (2004) emphasis on the construction of a spatial-situational model (SSM) of the VE to be able to feel present in that VE. As the user begins to travel through the VE, this SSM is continuously updated by adjusting the mental map created of one's immediate surroundings (courtesy of one's mental rotation ability) following changes in visually available spatial cues from the environment. These processes aid the media-as-primary egocentric frame of reference (PEFR)-hypothesis proposed by Vorderer et al. (2003). The experience of presence in the VE occurs when spatial cues supporting the media-as-PEFR-hypothesis is stabilized[86]. Thus, mental rotation ability (and associated mental maps) plays a crucial role in this stabilization process as it helps to continuously update the SSM and the person's orientation in the VE. Further, this complete mental presentation of the environment and the sense of presence experienced within it are also likely to influence the user's performance in the environment. The more complete and stable the mental representation of the environment is, the better users will be at orienting themselves in that environment. As interacting with VEs does not follow the exact same laws as the physical environment, previous experience with such VEs is also likely to affect the ease with which spatial cues from a VE are obtained, interpreted, and applied for navigational purposes, as well as the level of presence experienced in that VE. This literature review led to three main hypotheses regarding the relationship between the experience of presence in VEs and spatial abilities:

1) Maze performance is determined by a user's level of presence which, in turn, is determined by *relevant* spatial abilities. Specifically, it is predicted that better maze performance will correlate with high levels of presence, high mental rotation ability, and high use of mental maps to aid navigation. Because it is believed that presence is partly determined by spatial ability, it is also predicted that the unique contribution of presence will be small when overlap with mental rotation ability is controlled for.

[86] See section 2.1.5.1.1 in chapter 2 of this thesis for a fuller description of this theory.

2) Gender differences in maze performance are explained by differences in *relevant* spatial abilities. Since the VE used in the study does not include cues that support an object location memory strategy, it is likely that men will perform better on the maze task than women. This hypothesis is further based on the hypothesis that men will score higher than women on the mental rotation task, and that men are also more likely than women to apply mental maps to aid navigation. In contrast, high scores on object location memory will not be associated with better performance on the maze task.

3) Users' level of digital game play experience affects the level of presence experienced in a VE. High experience with playing digital games is likely to correlate positively with level of presence and maze performance.

The following chapter reports an empirical study conducted to test these hypotheses.

4 METHOD

The present study applied a quasi-experimental design to investigate the relationship between the experience of presence in virtual environments (VEs) and spatial abilities. Participants were asked to complete two tests of spatial ability and to navigate through a virtual maze. On the basis of their performance on these spatial ability tests and their interaction with this VE, the relationship between presence in a VE and spatial abilities was assessed. Other variables, such as the use of mental maps and previous experience with playing computer games were also investigated.

4.1 Participants

A total of 50 participants consented to take part in the study. The sample consisted of 22 males and 28 females between the ages 18 to 42 (M: 27.06 and SD: 6.5). Participants were recruited from Massey University undergraduate classes and the general public. With permission from the respective Head's of School and course coordinators at Massey University, university participants were approached before or after class. At that time, potential participants were handed an information sheet and a contact details form (see appendix A). Some participants were also recruited through poster advertisement (see appendix A) and "word of mouth". A second copy of the information sheet and a consent form (see appendix A) were provided on the day of the actual experiment. Written consent from participants was obtained just prior to the individual experimental sessions.

One selection criterion was applied, namely that of handedness. Handedness has been associated with the lateralization of the brain. The direction and degree of handedness has been found to be more closely related to the functioning of the hemisphere contralateral rather than ipsilateral to the preferred hand (Beaton, 2003). Annett (1985, cited in Casey, Pezaris, & Nuttall, 1992) and Geshwind and Galaburda (1987, cited in Casey, Pezaris, & Nuttall, 1992) suggest that right-handers with right-handed relatives are more likely to be left-hemisphere dominant for language and use more analytic rather than spatial strategies for solving problems. One way of investigating sex differences in spatial abilities is to look at hemisphere specialization or lateralization. Male superiority on spatial tasks, for example, has been attributed to a female bias for bilateral representation of language (which interferes with the development of neural circuits for spatial ability), or bilateral representation of spatial ability (which is less efficient that unilateral representation) (McGlone, 1980 cited in Crucian & Berenbaum, 1998). This relationship between lateralization and ability may further be moderated by handedness (Birkett, 1980, cited in Crucian & Berenbaum, 1998). Research in the area of spatial ability (Harshman, Hampson, & Berenaum, 1987) reports some interaction effects between handedness, general intellectual ability, and mental rotation scores. Controlling for handedness is a common procedure in spatial ability research (e.g., Moffat, Hampson, & Hatzipantelis, 1998; Siegel-Hinson & McKeever, 2002) and left-handed volunteers were excluded from the present study to avoid interaction effects between handedness and spatial ability.

4.2 Design

The present research used a quasi-experimental design. The main independent variables included gender, spatial ability (as measured by mental rotation ability and object-location memory ability), and the experience of presence in a VE. The main dependent variable was performance on a virtual maze task. This performance was measured by maze time and maze error (see below for a definition of these terms). Other independent variables included the use of mental maps to navigate the virtual maze and previous experience with playing digital games. Presence was also examined as a dependent variable in a secondary analysis.

4.3 Apparatus and Stimuli

4.3.1 The Screening Questionnaire

A short screening questionnaire (see appendix B) was developed to obtain information about two potentially influential variables: handedness and previous experience with playing digital games. As mentioned above, people who considered themselves to be left-handed were not included in this study. Further, Stanney, Mourant, and Kennedy (1998) argue that VE "experience level influences the skill of the user, the abilities that predict performance, and the manner in which users understand and organize task information" (p. 333). This means that high levels of experience may lead to higher user skills which in turn would affect the way in which the user interacts with the VE. Experience is also likely to affect the "manner in which users mentally represent a virtual environment over time" (Stanney et al., p. 333). Playing digital games is a very common source of entertainment, and such experience is especially relevant when considering user interaction with *desktop* environments. As the study described in this thesis applied a desktop environment to investigate presence, previous experience with playing digital games was examined. Information regarding participants' experience with playing first person perspective (FPP) or third person perspective (TPP) digital games was also gathered. As discussed in the previous chapter, a FPP (i.e., no visually available avatar) may demand increased mental rotation ability and an increased ability to contain spatial information in short term memory in order to comprehend one's spatial surroundings as compared to a TPP (i.e., visually available avatar). People's experience with playing digital games was measured according to five response options: 1) never, 2) infrequently, 3) once a week, 4) every day for less than two hours, and 5) every day for more than two hours.

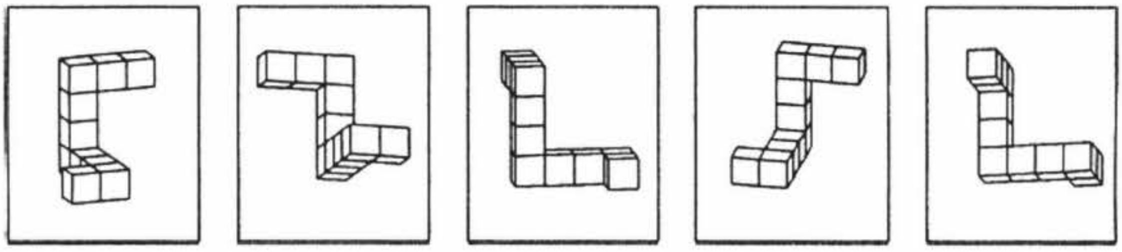
4.3.2 The Mental Rotation Test (MRT-A)

Mental rotation was measured by the Mental Rotation Test (MRT-A) (Peters, 1995)[87]. This test is composed of figures created by Shepard and Metzler (1978, cited in Peters, 1995) and is essentially a redrawn version of the Vandenberg and Kuse (1978, cited in Peters, 1995) MRT test. The MRT-A contains 24 test items, or problem sets. Each problem has a target figure shown on the left and four stimulus figures on the right (see Figure 4.1). Two of the stimulus figures are rotated versions of the target figure, and two of the stimulus figures cannot be matched to the target figure. Before commencing the actual test, participants were introduced to the nature of the task by completing a number of practice problems. At first the participants were asked to familiarize themselves with the way the figures are rotated around their vertical axis in the test. Secondly, they were presented with an example of how to identify the two correct answers among four stimulus figures. Another three practice examples were then provided for the participants to feel comfortable about understanding the aim of the task. The test itself contains four pages of problem sets. The participants were given three minutes to complete the first two pages, followed by a one minute break. After the break, they were given another three minutes to complete the last two pages. The participants were informed that they would have to identify both correct answers on each individual problem set to receive a point for that set. This measure has good face validity as the task at hand clearly indicates the mental rotation of an object. In addition, the nature of this task shares strong similarities to other measure of 'spatial visualization' such as the Form Board Test and the Paper Folding Test (Ekstrom, French, Harman, & Dermen, 1976, cited in Flynn, 1996). Further, the test has been found to demonstrate robust and reliable evidence of individual differences on the task (e.g., Silverman & Eals, 1992; Collins & Kimura, 1997; Peters, 2005; Choi & L'Hirondelle, 2005), which indicates the test taps into a particular area of spatial ability. However, much discussion still remains as to whether mental rotation is a separate spatial ability factor per se, or part of an overall spatial ability factor[88].

[87] A copy of this test is not included in the appendixes due to copyright restrictions. To obtain a copy of the MRT-A please contact Michael Peters, Professor at the Department of Psychology, University of Guelph, Canada, e-mail: mpeters@uoguelpg.ca, ph: 519 824-4120, 53597.

[88] See chapter 4 for a fuller discussion of this issue.

Figure 4.1 Example of test item from the MRT-A.



The task is to match the target figure (i.e., the one on the far left) with two of the 4 stimulus figures. Copied from Peters (2005).

4.3.3 The Object-Location Memory Test

Object-location memory was measured by an object-location memory test developed by Silverman and Eals (1992)[89]. The test itself consists of three pages depicting a range of common objects arranged in random order (see Figure 4.2). The three test sheets include: 1) a sheet of 27 objects; 2) a sheet with the same objects located in the same location as in sheet number 1, but with the introduction of another 20 objects; and 3) a sheet with the same objects as in sheet number 1, but where some of the objects have changed location. First, participants were given one minute to study sheet number 1. After one minute had passed, they were shown the second sheet. Now they were given one minute to identify the new objects that had been added to sheet number 1. Finally, the participants were introduced to sheet number 3 and given another one minute to locate which objects were in the same location as before and which objects had been moved to a different location. The test has good face validity. In addition, Silverman and Eals (1992) showed that the results obtained on the OLMT correspond well with results obtained from a real-world setting[90] (i.e., evidence of convergent validity). Several studies also show that the OLMT is sensitive to individual differences on this task (Silverman & Eals, 1992; Choi & L'Hirondelle, 2005)

[89] To obtain a full-size copy of the OLMT test sheets please contact Jean Choi, Assistant Professor at the Department of Psychology & Neuroscience, University of Lethbridge, Canada, e-mail: jean.choi@uleth.ca, ph: 403 380-1863.

[90] Silverman and Eals (1992) constructed a naturalistic setting (i.e., a room with objects in it) to see if results on the OLMT diverged from results obtained from this real-world setting.

however, these findings are somewhat tentative. It has been suggested that these individual differences may be a result of differences in underlying verbal memory skills, rather than object-location memory skills per se (Choi & L'Hirondelle, 2005).

Figure 4.2 The Object-Location Memory Test.

4.3.4 The MEC Spatial Presence Questionnaire (MEC-SPQ)

The MEC Spatial Presence Questionnaire (MEC-SPQ) (Vorderer et al., 2004) (see appendix B) was used to assess participants' the level of presence experienced in the VE. As previously mentioned, the MEC-SPQ involves eight scales[91]: 1) attention allocation (AA); 2) spatial situation model (SSM); 3) spatial presence (self location) (SPSL); 4) spatial presence (possible actions) (SPPA); 5) higher cognitive involvement (HCI); 6) suspension of disbelief (SoD); 7) domain specific interest (DSI); and 8) visual spatial imagery (VSI). This questionnaire can be used in one of three versions: 1) 4 items per scale; 2) 6 items per scale; or 3) 8 items per scale. In the present study, the 6-item scale was used meaning that all eight scales included 6 items each. All subscales (of 6 items each) contain high internal consistency (Cronbach's alpha): AA, r = .91; SSM, r = .87; SPSL, r = .92; SPPA, r = .86; HCI, r = .74, SoD, r = .86; DSI, r = .92; and VSI, r = .80 (Vorderer et al., 2004). The questionnaire uses a 5-point Likert scale. Thus, each scale has a minimum score of 6 and a maximum score of 30. The complete MEC-SPQ has a minimum score of 40 and a maximum score of 240. The questionnaire's high inter-scale correlations indicate that these scales are

[91] See chapter 3 'Measuring Presence', section 3.1.5, for a full description of this measure and its individual subscales.

all valid measures of the presence construct, which further supports the underlying theory of the MEC SPQ (Böcking et al., 2004a). Although these intercorrelations ranged from .10 to .78, only two out of 36 intercorrelations did not reach statistical significance (i.e., SPSL/SoD and VSI/SoD). See chapter 3 for a full description of this measure.

4.3.5 Map Creation

Research on spatial ability has shown that males and females tend to differ in the degree to which they utilize mental maps to aid navigation. Specifically, men tend to use more mental maps to aid navigation than do women (Choi & Silverman, 2003). Due to this identified gender difference in using mental maps during navigation, participants were asked to self-report their use of mental maps during the maze solving task. After finishing the maze task, participants were asked; "Did you create a mental map of the maze to help you find your way out of the maze?" A mental map was defined as a mental image of the maze layout.

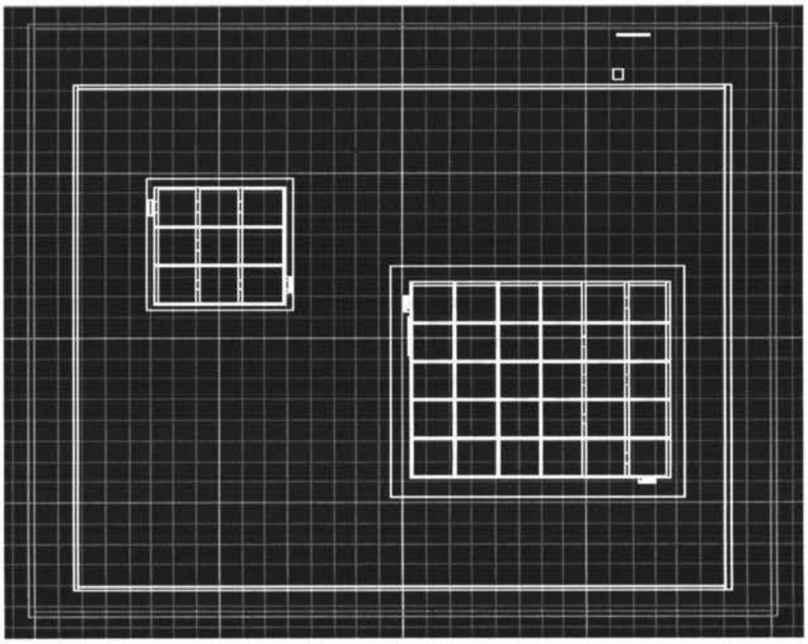
4.3.6 The Maze

The virtual 3D maze (see Figures 4.3 and 4.4) was built by using the 3DGameStudio software version A6[92] (Conitec Datensysteme, 2000). This job was done by the computer technician at Massey University, Malcolm Louden, using the researcher's maze designs. This software allowed for the creation of a fully enclosed "space" including both ground and sky. The ground was given a grass texture upon which the virtual maze was built. This grass area was surrounded by a fence to properly define the area within which the participant would move around during the experiment. Mountain ranges served as a background surrounding the experimental area. There were two mazes placed on the grass inside the fenced area. Maze 1 (i.e., practice maze) consisted of a 3x3 room layout, and Maze 2 (i.e., test maze) consisted of a 5x6 room layout. Participants could walk forwards, backwards, left, and right using the keys W, S, A, and D respectively. They could also change their facing

[92] The 3D Game Studio software can be bought via their website: http://www.3dgamestudio.com/.

direction by moving their mouse with their right hand. These are the same interface keys most commonly used when playing computer games (i.e., PC games).

Figure 4.3 Maze floor plans.



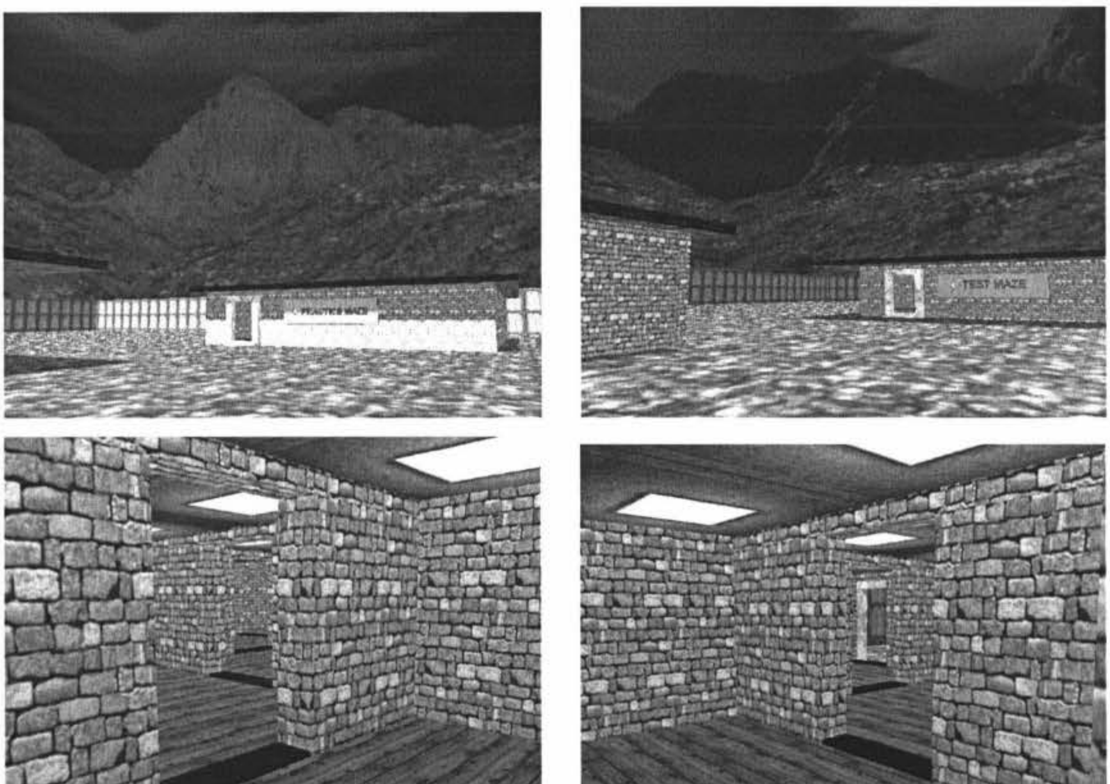
Several architectural constraints were applied in an attempt to maximize the possibility of finding statistically significant result associated with this study's hypotheses:

1. Based on the theorized link between FPP and spatial ability, participants were only able to traverse the VE from a FPP[93]. This was applied to be able to examine the ease with which males and females traversed the VE from a FPP rather than a TPP.
2. As research shows a gender difference in the type of strategies males and females use to navigate an environment (Choi & Silverman, 2003), very few specific landmarks or objects

[93] The researcher had originally intended to investigate the hypotheses underlying the present study by the use of a 4 x 4 matrix design which involved the differentiation of FFP and TPP conditions. That is, the original aim was to investigate gender differences related to performance on the maze task from both conditions. However, this design was replaced by the current quasi-experimental design due time constraints and the limited number of participants.

were available within the maze to help people remember where they were and to keep orientated. This was applied to put greater demands on the users' ability to hold and rotate complex spatial information in working memory (e.g., create a mental image or mental map of the immediate surroundings, components of the maze, and/or the complete maze). Some landmarks necessarily still existed, such as the difference between a room with one and two exit doors. However, as all the rooms in the maze looked exactly identical in terms of size and texture, the use of landmarks for orientation was limited.

Figure 4.4 Pictures from the VE/maze.



4.4 Procedure

Participants were tested one at a time. After having re-read the information sheet and signed the consent form, participants were asked to complete the screening questionnaire. When it had been determined that participants were right-handed, they were introduced to the first spatial ability test: the Object-Location Memory Test. When this test was completed, the MRT-A was introduced and completed. In the next step of the session participants were introduced to the VE and maze. All participants began the maze task in the same corner of the simulation (i.e., on the grass outside the mazes). The participants were then asked to walk up towards and around Maze 1 to familiarize themselves with the key board controls and mouse. After the initial familiarization with the interface of the VE, participants were asked to walk into the practice maze and find their way out. After having completed this task, participants were given the opportunity to look at both Maze 1 and 2 from the outside to compare the size of the two mazes. Participants were then asked to walk up to the actual test maze. Before entering the test maze, participants were told that the exit of the maze was located diagonally opposite to the entrance. After having successfully found their way out of the test maze, the participants were asked to answer the MEQ Spatial Presence Questionnaire. As a last question, participants were asked to report their use of mental maps to aid navigation in the maze. The same order of administration was followed for all participants. Each time period for the different procedures was measured by a stop-watch by the researcher. The total time taken for each session was approximately 35 minutes.

All procedures in this study were approved by the Massey University Human Ethics Committee prior to the commencement of the study. Participants were informed about the confidential nature of their individual results and their right to withdraw from the study at any time. They were also offered a summary of the findings from the research when the thesis has been completed and corrected.

5 RESULTS

5.1 Statistical Analysis

The four statistical analyses applied in this research were multiple regression, correlation, t-tests, and chi-square calculations. All analyses were performed using the SPSS computer statistical package version 12.0.1 for Windows (SPSS Inc., 2004). Also, Preacher's (2003) interactive calculation tool for chi-square tests was used to test for goodness of fit and independence for the chi-square calculations carried out.

5.2 Scoring

5.2.1 Scoring Previous Game Play Experience

As previously mentioned, information about participants' level of experience with playing digital games was obtained using a screening questionnaire (see section 4.3.1 of this thesis). This questionnaire applied five different response options: 1) never, 2) infrequently, 3) once a week, 4) less than two hours a day, and 5) more than two hours a day.

5.2.2 Scoring of Spatial Ability Tests, the Use of Mental Maps, and the MEC-SPQ

The MRT-A has a minimum score of 0 and a maximum score of 24. Participants were awarded 1 point for each time they were able to identify both correct items within a set of stimulus items.

The object-location memory test involved the calculation of two separate scores: one for object *location* and one for object *memory*. The location subtest allowed for a maximum score of 27 and the memory sub-test allowed for a maximum score of 20. Both tests' overall total score was calculated as the percentage of items correctly identified[94].

Mental map creation was scored according to yes (1) or no (0) criterion.

The MEC-SPQ scores were added up individually for each subscale. Following the instructions for scoring the MEC-SPQ provided by Vorderer et al. (2004), some items on the Suspension of Disbelief (SoD) subscale were reverse scored. The total score of each subscale was then combined into an overall spatial presence score.

5.2.3 Scoring Maze Performance: Maze Time and Maze Error

The maze task allowed for the recording of two measures of maze performance; maze time and maze error. Maze time was recorded as the number of seconds participants took to find their way out of the maze. This was done by running a program that registered the user entering the maze from the main entrance and exiting the maze at the exit door. This program was developed by the computer technician at Massey University, Malcolm Louden. Maze error was calculated as the number of doors traversed beyond the minimum number of doors (i.e., seventeen) necessary to find the exit door. Maze time was considered an appropriate measure of performance based on previous research on maze performance tasks (Basdogan et al., 2000) and the general assumption that people who are able to keep oriented in a maze are likely to find the exit faster than people who lose track of where they are in the maze. Maze error was added as an additional measure of performance as it is appropriate to assume that people who keep oriented in the maze are likely to commit fewer errors than people who get disorientated within a maze.

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[94] The researcher had originally intended to use signal detection theory to score the OLMT. Using this theory could have provided a more accurate measure of participants' performance on the OLMT in the present study. However, using signal detection theory did not allow for the creation of a combined score for the OLMT (see section 5.3) and a decision was therefore made to instead use percentages as a measure of performance.

5.3 Transformation of Data

First, the two scores of the object-location memory test (OLMT), the location and memory subtests, were combined into one composite score. The purpose of doing this transformation was to increase the power of the multiple regression analyses. In addition, this score produced an overall score involving a type of spatial ability where it has been claimed that females tend to perform better than males (Silverman & Eals, 1992). Thus, the percentage scores for both subtests of the OLMT were combined into an overall object-location memory score. The MRT-A score serves a similar purpose by providing a score on a spatial ability task where males generally perform better than females.

In the present study, the variables maze time and maze error produced distributions of scores that did not fall neatly into a normal distribution. As the statistical procedures applied in this study rely on the assumption of normally distributed scores[95], these variables were transformed using logarithmic transformations (see Tabachnick & Fidell, 1996)[96].

The screening questionnaire used in the research reported in this thesis consisted of a categorical scale indicating people's level of experience with playing digital games. The use of a categorical scale implied that chi-square calculations would be an appropriate statistical analysis to investigate this data. Preacher (2003) argues that the use of chi square tests is inappropriate if any expected frequency is below one or if the expected frequency is less than five in more than 20% of a particular response options, or cells. The raw data obtained from the screening questionnaire indicated that this was the case in the present study (see section 5.6 of this chapter). Thus, to avoid this problem, participants' responses to the screening questionnaire were clustered into three main categories: 1) low (never), 2) medium

[95] The assumption of normality is that if all possible scores within a population (as opposed to the sample normally used in research) are taken into consideration, the distribution of scores will fall into the shape of a bell curve (i.e., normal distribution).

[96] Tabachnick and Fidell (1996) argue that transformation of scores always should be considered unless the distribution of scores is already normally distributed. They suggest that, if the scale in which the variable is measured is not widely used, but arbitrary, then interpretation of transformed data will be similar to that of the original data (although the transformation procedure necessarily is taken into account). The most important consideration is to check that your variable is normally or close to normally distributed after transformation. They also note that transformation is only useful when some, but not all of the variables in an equation needs transformation. This was the case for the study described in this thesis.

(infrequently), and 3) high (once a week, less than two hours a day, or more than two hours a day).

5.4 Descriptive Statistics and Gender Differences

Mean scores were obtained for both genders on all variables. Table 5.1 shows the means and standard deviations of male and female scores on the maze performance variables maze time and maze error.

Table 5.1 Descriptive statistics of maze performance variables (untransformed).

	Males		Females	
Variable	Mean	SD	Mean	SD
Maze Time (sec.)	142.36	108.64	193.21	126.66
Maze Error	48.68	37.34	50.54	40.17

Two-tailed independent samples t-tests were carried out on these maze performance scores. No significant gender difference was found on either maze time ($t(48) = 1.65$, $p = .11$) or maze error scores ($t(48) = -.04$, $p = .97$).

Table 5.2 shows the mean and standard deviations of male and female scores on the MEC-SPQ, including the eight subscales. These results correspond well with other studies that have used the MEC-SPQ to investigate presence in VEs other than desktop environments, which adds some validity to the use of a desktop environment in the present study (McCall, O'Neill, Carroll, Benyon, & Smyth, 2005; Gysbers, Klimmt, Hartmann, Nosper, & Vorderer, 2004)[97].

Table 5.2 Descriptive statistics for the MEC- SPQ

	Males		Females	
Variable	Mean	SD	Mean	SD
MEC-SPQ	163.77	21.54	160.32	32.08
MEC-AA	23.73	6.18	22.36	4.95
MEC-SSM	21.86	3.90	18.82	6.18
MEC-SPSL	19.14	5.40	19.89	6.09
MEC-SPPA	18.77	5.40	19.82	5.74
MEC-HCI	17.82	5.42	18.18	4.58
MEC-SoD	21.50	3.75	24.89	3.87
MEC-DSI	18.45	5.30	15.75	7.41
MEC-VSI	22.50	4.42	21.07	5.14

MEC-SPQ = MEC Spatial Presence Questionnaire, MEC-AA = Attention Allocation, MEC-SSM = Spatial Situation Model, MEC-SPSL = Spatial Presence: Self Location, MEC-SPPA = Spatial Presence: Possible Actions, MEC-HCI = Higher Cognitive Involvement, MEC-SoD = Suspension of Disbelief, MEC-DSI = Domain Specific Interest, and MEC-VSI = Visual Spatial Imagery.

Further, Table 5.2 indicates that there was no major difference between males and females in terms of the overall level of presence they experienced in the VE/maze ($t(48) = .43$, $p = .67$).

[97] McCall et al., (2005) investigated user's sense of presence in a VE characterized by a head-mounted display, or cave, while Gysbers et al. (2004) looked at people's experience of presence in a VE created by the interaction with a book.

However, males' experience of presence was more strongly associated with the creation of a spatial situation model (t (48) = 2.01, p = .05) of the VE than for females, while females' experience of presence was more strongly associated with the suspension of disbelief ($t(48)$ = 2.69, p = .01) than for males.

Table 5.3 shows the descriptive statistics for the two tests of spatial ability: MRT-A and OLMT. The results obtained on the spatial ability tasks showed that men did significantly better than females on the mental rotation ability task in this study ($t(48)$ = 2.80, p = .01). However, no significant gender differences were found on the OLMT location subtest ($t(48)$ = .29, p = .77), the OLMT memory subtest ($t(48)$ = .61, p = .54), or the overall OLMT score ($t(48)$ = .52, p = .60).

Table 5.3 Descriptive statistics for the MRT-A and the OLMT

	Males		Females	
Variable	Mean	SD	Mean	SD
MRT-A	12.32	4.09	8.86	4.54
% OLMT Location	58.59	21.46	60.58	25.68
% OLMT Memory	85.23	14.92	87.50	11.43
% OLMT Total	71.91	11.89	74.04	16.02

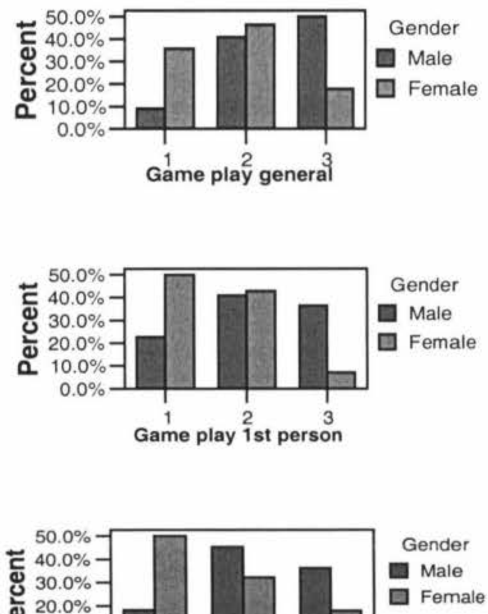
Table 5.4 shows the mean percentages for participants' creation and use of mental maps during the maze task. Chi-square statistics showed that males substantially more often used

mental maps during navigation in the virtual maze than females $\chi^2(1, N=50) = 11.06, p < .001$).

Table 5.4 Descriptive statistics for map creation.

Variable	Males	Females
Created mental map	68.2 %	21.4 %

Figure 5.1 Percentages of male and female participants for previous game play experience.



The numbers 1 to 3 indicate the following: 1 = never, 2 = infrequently, and 3 = once a week, less than two hours a day, or more than two hours a day.

Figure 5.1 shows that male participants had more experience with playing digital games than females participants in this study. Males tended to play more digital games than females in general (χ^2(2, N=50) = 7.70, p = .02), as well as more often from a first person perspective (FPP) than females (χ^2(2, N=50) = 7.68, p = .02). Further, results investigating the difference in male and female experience with playing digital games from a third person perspective (TPP) approached significance (χ^2(2, N=50) = 5.66, p =.059), suggesting that males tend to also play games from a TPP more often than females.

5.5 Inferential Statistical Analyses

First, a number of separate multiple regression analyses were conducted. The first four multiple regression analyses were carried out to examine the degree to which scores on the maze performance task could be accounted for by level of presence, spatial ability, and gender. Only 9.7% of the variance in maze time could be accounted for by presence, mental rotation ability, and gender (adjusted R^2 = .097, F(3, 46) = 2.76, p = .053) however, the overall model was very close to reaching statistical significance. Further, neither presence (β = .27, t(46) = 1.94, p = .06), mental rotation ability (β = .12, t(46) = .79, p = .43), nor gender (β = .17, t(46) = 1.16, p = .25) were significant predictors of maze time, although the presence variable came very close to being a significant predictor. In the second model, maze time was replaced by maze error as DV. In this case, presence, mental rotation ability, and gender did not account for any of the variance in maze error scores. These two models were then adjusted by replacing scores on the MRT-A with scores on the OLMT as an indicator of spatial ability. Thus, the third model included maze time as DV, and presence, object-location memory ability, and gender as IVs. This model accounted for only 10.7% of the variance in maze time (adjusted R^2 = .11, F(3, 46) = 2.97, p = .04), although it did however reach statistical significance. Nevertheless, only presence reached statistical significance as individual predictor of maze time (β = -.31, t(46) = 2.26, p = .03). The last model involving presence, object-location memory ability, and gender as IVs did not account for any major change in maze error scores (adjusted R^2 = .00, F(3, 46) = 1.07, p = .37).

Second, a multiple regression analysis was conducted to investigate the relationship between presence (DV), mental rotation ability, object-location memory ability, and gender (IVs). This model only accounted for 7,2% of the variance in presence levels ($R^2 = .07$, $F(3, 46) = 1.19$, $p = .33$) and did not meet statistical significance. Out of the three IVs mental rotation ability came somewhat close to being a significant individual predictor of presence ($\beta = .28$, $t(46) = 1.78$, $p = .08$). The multiple regressions did not reach statistical significance for many analyses probably because of low sample size[98].

Third, a one-tailed correlation analysis using Pearson's product moment correlation was applied to investigate the relationships between variables (see Table 5.5). Not surprisingly, maze time strongly correlated with maze error ($r(48) = .88$, $p < .001$). In addition, performance on the maze task in terms of maze time scores significantly correlated with the experience of presence ($r(48)= -.31$, $p = .01$) and mental rotation ability ($r(48) = -.25$, $p = .04$), and the use of mental maps to aid navigation ($r(48) = -.50$, $p < .001$). Also maze error significantly correlated with the use of mental maps for navigation($r(48) = -.14$, $p < .001$). Further, presence significantly correlated with mental rotation ability ($r(48) = .24$, $p = .05$). The relationship between presence and maze error did not reach statistical significance, but did suggest that these variables may correlate if the sample size had been higher ($r(48) = -.19$, $p = .10$).

In addition, the same type of correlational analysis was performed to investigate the relationship between the individual MEC-SPQ subtests and the variables listed in Table 5.5[99]. Maze time significantly correlated with the subscales Spatial Situation Model (SSM) (r (46) = -.53, $p < .001$), Visual Spatial Imagery (VSI) ($r(46) = -.29$, $p = .02$), and Attention Allocation (AA) ($r(46) = -.24$, $p = .04$). Maze error correlated significantly with the subscale SSM ($r(46) = -.40$, $p < .001$) and was very close to a significant correlation with VSI ($r(46) = .23$, $p = .06$). Mental rotation ability correlated significantly with the subscales SSM ($r(46) = .44$, $p < .001$), Domain Specific Interest (DSI) ($r(46) = .32$, $p = .01$), VSI ($r(46) = .39$, $p <$

[98] Two common rules of thumb for calculating the appropriate sample size for a multiple regression analysis are: 1) 50+(8x no. of IVs) and 2) 104+no. of IVs (Spicer, 2005). For the current analyses this suggests that sample sizes of 74 to 107 are required – considerable more than has actually been used. The analyses can thus only be taken to be suggestive of the nature of the relationships that hold between the variables of interest.

[99] See Table 5.6 in appendix C for the complete matrix of these correlations.

.001), and Suspension of Disbelief (SoD) ($r(46) = .26, p = .03$), while the use of mental maps for navigation significantly correlated with SSM ($r(46) = .40, p < .001$), SoD ($r(46) = -.27, p = .03$), DSI ($r(46) = .25, p = .04$), and VSI ($r(46) = .28, p = .02$).

Table 5.5 Intercorrelations between maze task, presence and spatial ability variables.

Variables	Maze Time	Maze Error	MEC-SPQ	MRT-A	OLMT(L)	OLMT(M)	OLMT(T)	Map
Maze Time	-	.88**	-.31*	-.25	-.18	.09	-.11	-.50**
Maze Error		-	-.19	-.06	-.23	.07	-.16	-.41**
MEC-SPQ			-	.24	-.14	.11	-.07	.21
MRT-A				-	.10	.26	.20	-.41**
OLMT(L)					-	.13	.89**	.06
OLMT(M)						-	.57**	-.12
OLMT(T)							-	-.001
Map								-

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level.
OLMT(L) = Location, OLMT(M) = Memory, and OLMT(T) = Total.

Last, the variables presence, maze task performance, mental rotation ability, and map creation were investigated in relation to participants' previous game play experience. Results from the chi-square calculations applied showed no significant relationships between participants' level of presence in the VE and game play experience, or between performance on the maze task and game play experience. However, mental rotation ability was significantly related to general game play experience (χ^2 (2, N=50) = 51.37, p = .02), approached significance for its relation to FPP game play experience (χ^2 (2, N=50) = 43.55, p = .08), but was not significantly related to TPP game play experience (χ^2(2, N=50) = 39.93, p

= .16). A significant relationship was also observed between the use of mental maps and FPP game play experience (χ^2 (2, N=50) = 9.04, p = .01). In contrast, the use of mental maps was not significantly related to general game play experience or TPP game play experience.

5.6 Discussion

The regression models only accounted for a small amount of variance in the dependent variables tested in this study (i.e., maze time, maze error, and presence). However, some interesting tendencies emerged. These tendencies were supported by correlation analyses, t-test information, and chi-square test information. The results of this study provided some support for the hypothesis that maze task performance in a VE is related to the sense of presence experienced in that VE. In addition, six findings in particular indicated that mental rotation ability, but not object-location memory, played a mediating role in this relationship: 1) mental rotation ability, mental map creation, presence, and maze performance all correlated with each other; 2) object-location memory did *not* correlate with presence and maze performance; 3) a gender difference was observed on mental rotation ability, mental map creation, and on the maze performance task favouring males over females, but no gender difference was observed on the object-location memory task; 4) although no gender differences in the overall experience of presence in the VE was observed, males tended to associate their sense of presence more strongly with the construction of a spatial situation model of the VE than women; 5) construction of a spatial situation model of the VE strongly correlated with scores on the mental rotation test, mental map creation, and maze performance; and 6) maze performance was also related to the presence factor visual spatial imagery. Thus, the present findings indicate that gender and gender differences in mental rotation ability may affect user's experience of presence in VEs, which again may affect user's performance in those VEs. However, due to the small sample size of the present study these results should be taken as suggestive of such a relationship rather than as evidence for it. In addition, robust gender differences were found for previous game experience, and although such experience did not seem to be related to the experience of presence per se, it may have mediated the nature of maze task performance due to user's familiarity with the VE interface design. Further, both mental rotation ability and the use of mental maps related to specific aspects of game play experience, which indicates that participants' preference for FPP versus TPP game play, may possibly be influenced by these factors. The following is a summary of the main relationships observed from the present study.

5.6.1 Maze Performance, Presence, and Spatial Ability

The speed with which participants traversed the maze related to their overall experience of presence in the VE. Thus, this finding provides further support to Youngblut and Huie's (2003) findings of a positive correlation between presence and performance in VEs. Not surprisingly, maze time and maze error also strongly correlated with each other, which supports Nash, Edwards, Thompson, and Barfield's (2000) suggestion that both maze time and maze error may be useful measures of performance in VEs. A small correlation was also observed between maze error and presence. However, by contrast with maze time, the relationship between maze error and presence did not reach statistical significance in the present study. The fact that only maze time significantly correlated with presence although maze time and maze error strongly correlated with each other, may be explained by the way in which participants traversed the maze. Observations made during the experimental sessions indicated that participants with different levels of experience approached the maze task in very different manners. People with high levels of experience with VEs (i.e., mostly males) tended to move faster and with less caution through the maze than novice users (i.e., mostly women). That is, increased experience seemed to lead to faster movement within the maze, probably due both to being familiar with moving in VEs (e.g., digital games) and familiarity with using the keyboard and mouse to execute these movements. Thus, the manner in which participants approached the maze task is likely to have influenced the number of doors they went through. In the present study it seems that participants with fast completion times on the maze task not necessarily also made few errors. This may be one of the reasons why although maze time and presence correlated, maze error and presence did not follow this same pattern.

Maze time and maze error were also related to certain specific underlying processes of presence (as measured by the MEC-SPQ). Participants who associated their experience of presence with the creation of a spatial situation model (SSM), the use of visual spatial imagery (VSI), and high attention allocation (AA) were also the fastest in navigating the maze. Creation of a SSM and the use of VSI also seemed to lead participants to commit fewer errors while navigating. Both maze time and presence showed a strong relationship with mental rotation ability. In addition, maze time and mental rotation ability also strongly correlated with mental map creation. This suggests that participants who did well on the mental rotation task and who tended to use mental maps to aid navigation, not only felt more present in the maze, but also did well on the overall maze task. This supports Galea and Kimura's (1993) findings of a relationship between mental rotation ability and maze navigation. In addition, the observed relationship between mental rotation ability and presence supports Vorderer et al.'s (2004) argument that visuo-spatial ability plays an important role in the experience of presence in VEs. This relationship was further supported by the strong relationship between mental rotation ability, mental map creation, and two subscales of the MEC-SPQ that focus on spatial skills: SSM and VSI. The SSM focuses on users' ability to construct a spatial-situational model of the VE and the VSI focuses on the ability to create mental representations of one's surroundings. Thus, both processes involve users' ability to hold complex spatial information in working memory (e.g., mental imagery). This ability is also an important factor in mental rotation as information during mental rotation tasks are manipulated in working memory by holding and rotating mental representations, or images. Similarly, mental maps are mental images created and held in working memory to aid navigation. It is important to note that object-location memory did not correlate with any of the MEC-SPQ subscales, nor with presence overall, or maze performance[100]. Thus, mental rotation ability may be a more important spatial skill in the

[100] The difference in results between the regression model involving object-location memory to investigate maze time performance ($p = .042$) and the model involving mental rotation ability (p. = .053) can be explained by the interaction effects that occur between the IVs in these regression models: when mental rotation ability and presence were combined within the same model, the interaction between these two variables would have reduced their individual effect on maze time (e.g., a relationship between these two variables was observed from the correlation analyses). In contrast, when mental rotation ability was replaced by object-location memory within this regression model, the individual effect of presence appeared larger than in the first model due to the fact that object-location

facilitation of presence than object-location memory, which again provides some support for the theoretical differentiation of these two constructs (i.e., mental rotation involves the ability to *generate* vivid visuo-spatial mental images, while object-location memory involves *remembering* visuo-spatial information). In addition, creating a mental map of the environment may also support this development of a sense of presence in the user.

5.6.2 Gender Differences

Although the results indicated that males tended to spend somewhat less time than females solving the maze task, these results did not reach statistical significance. One factor in particular may help explain these findings, namely previous experience with playing computer games. In the present study, males had more previous experience with playing computer games than females. As mentioned in the section above, observations made during the experimental sessions indicated that participants with different levels of experience approached the maze task in very different manners. While high experience with playing digital games led to higher speed of movement within the maze, it did not also lead to faster completion times. In contrast, observations showed that moving fast within the maze sometimes led participants to become disoriented in the maze. One explanation for this may be that these participants focused more attention on movement compared to keeping themselves oriented in the maze. When participants were asked about their performance, expectations about the difficulty level of the maze seemed to influence this shift in attention (i.e., expecting an easy maze led people to spend less attentional resources on orientation in the maze and more on moving fast through it). The tendency for males to do this more often than females can be explained by males having more familiarity with the interface design and thus finding it easier to move fast through the maze.

Males and females did not differ significantly in the degree to which they experienced a sense of presence in the VE overall. However, some gender differences in underlying

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memory accounted for less of the variability in presence than did mental rotation ability (e.g., no relationship between object-location memory and presence was observed from the correlation analyses).

processes affecting participant's level of presence in the VE were observed. While the creation of a SSM of the VE was an important factor in males' experience of presence in the VE, this was not the case for females. The creation of a SSM was strongly related to participants' mental rotation ability and use of mental maps in the present study. That is, high mental rotation ability and high use of mental maps was linked to a high likelihood that participants would associate their experience of presence with the creation of a SSM. A robust gender difference was observed on both the mental rotation task and participants' tendency to use mental maps, supporting previous findings reported by Choi & Silverman (2003), Kimura (1993, 1999), Moffat, Thompson, & Hatzipantelis (1998), and Silverman & Eals (1992) that males tend to perform better than females on such mental rotation tasks and more commonly apply mental maps as a strategy for navigation.
Thus, observed gender differences in these spatial abilities fit with the tendency for males to associate their experience of presence with the construction of a SSM of the VE in the present study.

Further, females were not significantly better than males at object-location memory and this ability did not seem to be particularly important for experiencing presence in the VE, nor for the overall performance on the maze task. This finding was also supported by results from the regression analysis examining the relationship between presence, mental rotation ability, and gender. Thus, males' experience of presence in the VE may have been more strongly associated with spatial skills than for females. On the other hand, women's' experience of presence was more strongly associated with suspension of disbelief (SoD) than for men. Previous experience with playing digital games may help explain some of this difference. Participants with much previous game experience (i.e., mostly males) may have had higher expectation of the quality of the VE than those with less previous experience (i.e., mostly females). The present study used a relatively simple VE in terms of physics and environmental detail. As males had more experience with playing digital games than females, this may have made the VE interface less 'transparent' for males than for females, thus making suspension of disbelief more difficult to occur for males than for females. The simplicity of the VE design may also be one of the reasons why males did not associate their experience of presence significantly more with domain specific interest (DSI) than females despite having more experience with playing digital games (i.e., previous experience with playing digital games may have had a negative affect on the experience of presence in this study)[101]. While spatial ability may have been more important for males than for females in participants' experience of presence in the VE, suspension of disbelief may have been more important for females than for males. Also, it is possible that the use of mental maps to aid navigation at times can "remove" the user from the (experience of being present in his or her) immediate environment. In this view, the person's attention is being removed away from his or her immediate visual field to that of an abstract map of the person's location within the maze[102]. Thus, although the use of mental maps was related to the SSM and VSI MEC subscales, it may be that the use of mental maps at times can reduce the experience of presence in a VE (i.e., in the present study mostly males' experience of presence in the VE). However, as mental maps are also involved in the perception of one's immediate surroundings (i.e., 'gaze view' mode), the role of mental map creation on the sense of presence in VEs is complex and may affect users' experience of presence in the VE different according to the *type* of mental maps that are being created (e.g., small scale vs. large scale maps). Next is a further discussion of the role of mental maps in FPP VEs.

5.6.3 Mental Rotation Ability, Mental Maps, and Game Play Experience

One of the aims of the present study was to investigate whether good mental rotation ability is an especially important factor for navigation of a VE from a FPP as compared to a TPP. The present study showed that males had far more experience with playing digital games than females. This related in particular to overall game play experience and experience with playing from a FPP. Although males also had more experience than females with playing

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[101] Interestingly, the DSI subscale significantly correlated with mental rotation ability and map creation, which may indicate that people with high mental rotation ability, and who commonly use mental maps to aid navigation, may have a preferred liking for solving maze tasks, or vice versa. This finding links the DSI subscale with 'male factors' such as mental rotation ability and the use of mental maps. A small tendency for males to associate their experience of presence in the VE with DSI more so than women, further suggest that a stronger relationship between these two factors may had been observed if the sample size had been larger and/or if the VE had been of more sophisticated quality.

[102] See discussion on Heidegger ('being-in-the-world') section 2.2.1, and Gibson (mental representation as a 'second-hand' version of human experience) section 2.2.2 of this thesis.

from a TPP, this difference was not statistically significant and is likely to be due to males having more experience than females overall rather than a specific preference for TPP games. Rather, these results indicate that while men tend to play games form both a FPP and a TPP, women tend to play games mostly from a TPP.

A closer investigation into the relationship between mental rotation ability and game play experience revealed that mental rotation ability only related to *overall* game play experience, and not to FPP or TPP game play experience. However, a significant relationship was observed between FPP game play and the use of mental maps. This finding supports Colle and Reid's (1998) theory of the importance of mental maps to aid navigation in what they refer to as the 'gaze view mode' that is, when an individual explores his or her immediate surroundings in all directions from a FPP[103]. As previously mentioned, Galea and Kimura (1993) further suggest that the use of mental maps and the ease with which such mental maps are used for navigation is related to people's performance on mental rotation tasks[104]. The strong correlation observed between mental rotation ability and mental map creation in the present study supports this finding. Thus, the present study provides some support, albeit tentative, for the hypotheses that mental rotation ability may play an especially important role in FPP VE navigation, and that this may have an influence on users' preference for FPP VEs or TPP VEs. Interestingly, research on motion sickness in more immersive VEs (e.g., FFP flight or driving simulators) indicates that females tend to experience more motion sickness than males in these environments (Mourant & Thattacherry, 2000, Stanney et al., 1999). Traversing a desktop VE pose similar demands on a person's ability to comprehend spatial information while moving as other, more immersive, VEs, as the user is traversing the desktop VE trough moving his or her avatar. Thus, mental rotation ability and the use of mental maps may also have an influence on the degree of motion sickness experienced by users of VEs.

[103] See section 4.3 of this thesis for a fuller description of the 'gaze view' mode.
[104] See section 4.4.2 of this thesis.

5.6.4 Limitations

One major limitation of the present study was the relatively small number of participants taking part. Having a small sample size relative to the number of predictor variables examined led to low levels of statistical power of the overall study design. The main difficulty with low statistical power is the reduced ability to detect small or medium differences or relationships among variables. The analyses conducted in this study suggest that a number of variables not accounted for within the regression analyses may have contributed to individual differences in maze task performance and presence scores. This also suggests that the size of the critical relationship between performance, presence, and spatial abilities may be relatively small and therefore require increased power to be reliably detected. Low power may have contributed to these results by decreasing the chance of detecting significant differences between variables from the regression analyses, differences that may have been detected if the sample size had been larger. Future studies should therefore make sure to have larger samples, especially if a larger number of predictor variables are to be examined.

The fact that the overall regression models only accounted for a small variance in maze performance supports Stanney, Mourant, and Kennedy's (1998) argument that a multitude of factors other than users' level of presence also influence performance in VEs (e.g., issues related to the task, the user, the media technology etc.). In addition, the MEC-SPQ is not sensitive to gradual fluctuations of presence during the VE experience. Participants' responses to the MEC-SPQ may therefore have been more influenced by the end of their VE interaction than the beginning of their VE interaction.

Because the present study bases itself on a traditional view of presence, factors related to other theories of presence were not specifically addressed. The MEC-SPQ includes some questions related to the possibilities for action offered by the VE (i.e., the Spatial Presence (Possible Actions) subscale) however, a thorough investigation of *affordances* (i.e., an idea adopted from the ecological view of presence) is not included. Further, the MEC subscale Spatial Presence (Self-Location) involves questions related to the perceived location of the user within the VE. However it does not focus on the experience of being *bodily* situated in that location per se (e.g., the embodied cognitive framework focus on the role of the body in facilitating the experience of presence in an environment). Rather, the MEC-SPQ bases its theory of self-location on the creation of a SSM of the VE and on the role of conscious and unconscious hypotheses-testing (i.e., of PEFR) in facilitating this process. In addition, the MEC-SPQ does not include any particular reference to the role of socio-cultural elements of the VE experience (i.e., as is the focus of the socio-cultural view of presence). Thus, the exclusion of other theories of presence and factors of presence derived from these theories limits the scope of the MEC-SPQ. Also, the theory underlying the MEC-SPQ assumes that the experience of presence either occurs, or does not occur, at any point during the VE interaction. However, it may be possible that an individual is able to feel present in both the physical world and the VE at the same time (Slater et al., 1994). This also poses the question of whether the virtual is best viewed as something separate from the real, or as an aspect of real world experience itself. The definition of virtual space used in this thesis implies that even daydreaming can be considered a form of interaction with a virtual space. That is, virtual space refers to a mentally created space which can occur both with *or without* the help of technological aids (e.g., listening to a narrated story can create a sense of presence in the environment presented for the listener, but although the (virtual) space the listener feels present in is mediated by the text (and the voice of the narrator)[105], it is by large a mentally created space). The traditional view suggests that real world experience is distinctly different from virtual world experience and that the experience of presence in the real world can be compared to the experience of presence in a VE. However, this assumption has not, nor may it ever, be completely verified. Taking into account other theories of presence different from the traditional view may thus shed light on aspects of the presence phenomenon that are not being accounted for by research conducted within the traditional paradigm.

[105] See the discussion of 'sensory breadth' in chapter 2 on Presence, section 2.2.2.

5.6.5 Relevance for Future Research

The present study could have been strongly improved by increasing its statistical power. This could have been done in two ways: 1) by increasing the study's sample size, or 2) by reducing the degree of 'noise' within the study's own design. For example, within the maze task, the length of time to complete the maze task and the number of doors people go through could easily be unreflective of an individual's 'true' spatial ability. That is, someone with low spatial ability may complete the maze task very quickly simply due to luck, while someone with high spatial ability may complete the task slower as a result of an unlucky start to the maze task (i.e., the beginning of the maze involved two doors, one which would lead the participant towards the exit of the maze and one that would not, accidentally choosing the "correct" door would lead to faster completion time than accidentally choosing the "wrong" door). In addition, the study design itself could be extended to involve a closer investigation of the differences in performance between FPP VEs and TPP VEs. For example, a 2 x 2 matrix design involving the variables FPP, TPP, males and females would have been able to provide more information about the relationship between gender differences in spatial ability, people's level of experience according to both FPP and TPP VE designs, and the ease with which users traverse these two different VE conditions.

The results of the present study are relevant for a number of areas of investigation within psychology. First, VEs are becoming increasingly popular tools for investigating human navigational and way-finding skills (Kozak, Hancock, Arthur, & Chrysler, 1993). The present study adds to this existing body of literature by focusing on the role of mental rotation ability to aid navigation in VEs (FPP VEs in particular). Because gender differences in spatial skills may affect individuals' level of performance in those VEs, it is important to structure VEs that facilitate navigation for both males and females. For example, in a navigation task such as a maze task, it is important to include spatial cues that facilitate both male and female strategies for navigation (e.g., include landmarks). Variation in these scenarios can also be used to investigate individual differences in other aspects of such navigational skills. Second, VE scenarios are currently being used in neuropsychological rehabilitation to teach specific spatial skills to individuals who experiences difficulties in these areas (Morganti, 2004). Thus, knowledge about individual factors that affect navigational performance in VEs is a valuable tool to aid such learning. Third, researchers and clinicians are currently exploring the usability of VEs as treatment tools within the field of clinical psychology. Research and practice in this area include the treatment of phobias (Anderson, Zimand, Hodges, Rothbaum, 2005; Rothbaum, Hodges, Smith, Hwan Lee, & Price, 2000;), social anxiety (Anderson, Rothbaum, & Hodges, 2003; Gershon et al., 2002; Zimand et al., 2003), post traumatic stress disorder (PTSD) (Difede, Hoffman, & Jaysinghe, 2002; Rothbaum et al., 1999; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001), panic disorder and agoraphobia (Botella et al., 2004) , eating disorder (Riva, Bachetta, Cesa, Conti, & Molinari, 2004), and burn pain (Hoffman, Patterson, & Carrougher, 2000) among others. These approaches to therapy commonly involve an immersive VE (e.g., head-mounted display) that is customized to treat the client's specific presenting problem(s). When using VR systems in this way, the experience of a sense of presence within the VE is an essential component of successful treatment (Hoffman, Richards, Coda, Richards, & Sharar, 2003). Thus, clinicians using such procedures must make sure to facilitate a sense of presence in the VE for the respective client. The present study suggests that gender differences in spatial skills and previous experience with interacting with VEs may affect the level of presence experienced, and performance, in VEs. Thus, the manners in which VEs are constructed and the type of spatial information provided to the users are important factors influencing effective treatment (e.g., the nature of the spatial information provided, the differences between FPP and TPP VEs etc.).

6 CONCLUSION

All virtual environments (VEs) involve the creation of a virtual space that enables the user to 'feel present' within the VE. A common term used to describe users' interaction with media in this way is *immersion*. However, within current psychological theories, immersion can refer to both the experience of a user and the qualities of the medium that elicit this experience (i.e., the *immersive qualities* of the medium). To better distinguish between the medium and the user in this context, theorists have come to use the term *presence* to refer to the phenomenological experience of 'being in' a VE.

A number of theoretical views have attempted to describe what this phenomenological experience is and how it occurs. First, the traditional view bases itself on rationalist and Cartesian views about reality and emphasise that presence in a VE can be understood by comparing it to the experience of presence in the real world. Within this view, the real, or physical, domain exists independently from the virtual, or mental, domain. The theoretical focus in this view is on mental representations. These representations of the VE are examined and compared to mental representations of the real world. Second, the ecological view emphasises the interdependent relationship between the person and the environment in understanding presence. From this perspective, mental representations relate to second-hand versions of what is real (such as pictures), and, thus, the topic of study is *not* the mental representations themselves, but the immediate interaction between the human and his or her environment. This view is based on the work of Heidegger and Gibson. While Heidegger opposes the Cartesian separation of the subject and the object, Gibson acknowledges the existence of physical properties in the environment and can be considered to hold a rationalist perspective on reality. Third, Sheridan's estimation theory attempts to bridge traditional and ecological views of presence. However, the meshing of different ontological and epistemological views within this framework can be criticized for going against the essence of what these theories suggest about reality and the nature of human experience. Fourth, the socio-cultural view of presence acknowledges the ecological position, but attempts to expand these ideas to include the cultural mediation of human experience. Finally, the embodied cognitive framework incorporates ecological ideas (e.g., Gibson's ideas of 'affordances') within a rational (i.e., 'traditional') framework to highlight the role of the physical body in the experience of presence in an environment.

Different ontological and epistemological frameworks offer different views on what 'reality' is and how we come to know of that reality. Attempts to combine such ideas within *one* framework at times seem to involve adjusting the original ideas to such an extent that the essence of those ideas is misrepresented. Thus, the current thesis bases itself on one theoretical framework only, namely the traditional view. However, perspectives offered by Gibson and the embodied cognitive framework (i.e., both rationalist views) have also been incorporated in the understanding of the presence construct used here. A working definition of presence derived from these views strongly emphasises the role of spatial abilities in creating an experience of presence in users of VEs. In particular, spatial abilities affect the construction of a spatial situational model of the VE. This model allows for the experience of the VE as a virtual *space* that the user can feel present in.

The focus of this thesis has been on the relationship between users' spatial abilities and the sense of presence experienced in VEs. Spatial abilities are understood to be affected by a number of underlying cognitive factors (e.g., attention, working memory capacity, processing speed etc.). In addition, it is acknowledged that both top-down and bottom-up processes affect perception and the generation of mental images. Due to individual differences in underlying cognitive processes, individual differences on different types of spatial ability tasks occur. In particular, males have been observed to perform better on mental rotation tasks than females. Males also tend to use mental maps to aid navigation more often than females. Several authors argue that mental rotation ability and the ability to generate and use mental maps share some relationship with each other (e.g., Colle & Reid, 1998; Galea & Kimura, 1993). According to Colle and Reid (1993), the use of mental maps is an integral part of navigation because it provides mental representations of one's immediate surroundings when traversing an environment from a first person perspective. Others have found a significantly positive correlation between mental rotation ability and navigational ability (Moffat, Hampson, & Hatzipantelis, 1998, cited in Ecuyer & Robert, 2004; Silverman et al., 2000). In contrast to the above findings, females tend to perform better on tests of object-location memory than males. A number of theories have been proposed to explain these gender differences, including strategy use (e.g., holistic vs. analytic strategies), biology (e.g., brain lateralization, hormones), and evolution (e.g., mating patterns, labour division etc.). Several authors have used this knowledge about spatial abilities and navigation in the real world to examine spatial behaviour in VEs. It has been found that the spatial knowledge acquired when navigating VEs is similar to that acquired in real world navigation. In addition, it has been shown that females find it more difficult to navigate a FPP VE than males (Waller, Hunt, and Knapp, 1998). It is possible that this occurs due to the increased demands of high mental rotation ability in FPP VEs. Further, a positive relationship has been observed between performance in VEs and users' level of presence (Witmer & Singer, 1998; Youngblut & Huie, 2003). Both performance and presence are affected by the spatial ability of the user.

The current study applied a quasi-experimental design to investigate the relationship between presence, spatial abilities, and performance in VEs. The results provided some support for the hypothesis that the experience of presence in VEs, and users' performance in VEs, is related to the spatial ability of the user. A significant gender difference on the mental rotation task and on the use of mental maps to aid navigation was observed. However, males did not feel significantly more present in the VE, nor did they perform significantly better on the maze task, than females. On the other hand, males tended to associate their experience of presence more strongly with the creation of a spatial situational model of the VE than women. Overall tendencies suggesting a link between mental rotation ability, the use of mental maps, and spatial aspects of the presence experience provide some indication that a relationship between these variables in a FPP condition exist. However, more research is needed to confirm this hypothesis.

Further, the findings of the present study suggest that gender differences in spatial abilities may have an affect on both the experience of presence in VEs and navigation in VEs. While men tend to associate their experience of presence in a VE with the construction of a spatial situational model of the VE, women tend to associate their experience of presence in VEs with the suspension of disbelief. Thus, such factors as the perceived 'realness' of the VE, the ease of interaction, the level of transparency of the medium and so on seem particularly important for the experience of a sense of presence in females. In addition, the fact that females tend to focus on environmental landmarks to aid navigation as opposed to the use of mental maps indicates that the presence of such landmarks in a VE is important to aid navigation for female users. A TPP VE condition provides a larger field of view (which includes a larger overview of the VE and its landmarks) than a FPP VE condition and may thus also positively influence the experience of presence (by keeping the user oriented) and navigation for females. In contrast, the influence of mental rotation ability and the use of mental maps on both the experience of presence and navigation in FPP VEs for male users suggest that a FPP VE condition may be more appropriate for males than females. These findings have implications for the use of VEs in spatial skills training, clinical psychology ('cybertherapy'), game studies, and VE engineering, among others.

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Appendix A

This appendix contains: Poster Advertisement, Information Sheet, Contact Details, and Consent Form.

IMMERSION IN VIRTUAL WORLDS

Male and female volunteers are sought to take part in an experimental psychology study. Participants will complete two short tests of spatial ability, navigate through a simple virtual environment, and answer questions from one questionnaire. The aim of the study is to investigate how spatial ability affects someone's experience of 'presence" (i.e. the sense of "being in" a world) in virtual environments such as computer games.

If you would like to participate, please contact Anne Hamarsnes Email: hamarsnesanne@hotmail.com to arrange a convenient time to participate.

This study is being conducted together with Dr. Stephen Hill from the School of Psychology (Ph: 356-9099, ext. 7566; S.R.Hill@massey.ac.nz. This project has been reviewed and approved by the Massey University Human Ethics Com[...] Wellington Application 05/22. If you have any concerns about the conduct of this research, please contact Professor Rumball, Chair, Massey University Campus Human Ethics Committee: WGTN telephone 06 350 5249, humanethicswn@massey.ac.nz.

Immersion in Virtual Worlds

How is your experience of 'being inside' a computer game affected by your ability to spatially orient yourself in the 'real' world?

INFORMATION SHEET

What is this study about and who is doing it?

The aim of this project is to investigate the effects of spatial ability on people's level of presence (i.e., sense of "being in" an environment) experienced within virtual environments (VEs) such as computer games. This particular experiment investigates whether two particular aspects of spatial ability – *spatial visualization* and *spatial memory* – affect the level of presence experienced in a VE.

The study will be conducted by Anne Hamarsnes, in collaboration with Dr. Stephen Hill in the School of Psychology, Massey University. Anne is a Master of Arts student in the School of Psychology at Massey University.

If at any stage you have any questions regarding this research, please feel free to contact Anne Hamarsnes in the following ways:

Email: hamarsnesanne@hotmail.com

Mail: **Anne Hamarsnes (c/- Dr. Stephen Hill)**
School of Psychology
Massey University
Private Bag 11 222
Palmerston North

If you should like to talk to someone in person about this project, you can contact Dr. Stephen Hill at the Massey Turitea Campus in Palmerston North:

Dr. Stephen Hill
Phone: **(06) 356 9099 ext. 7566**
Email: **S.R.Hill@massey.ac.nz**

How will participants be recruited for this study?

• Anne Hamarsnes will invite students to take part in the study during class time. Poster advertising on campus and "word of mouth" will also be used as recruitment procedures.

• You will need to sign and return a consent form before you take part in the study.

• This study will require approximately 100 participants for us to detect interesting differences between the experimental groups in the study.

Am I eligible?

If you wish to take part in this study you need to be right-handed. The reason for this is that handedness has been associated with cognitive abilities such as spatial ability, and the researcher needs to take account of this in order to ensure that the experiment works properly.

What will the study involve?

The study consists of three parts:

1. Part 1 involves answering questions about your background and previous experience with virtual environments, and the completion of two paper-and-pencil tests of spatial ability;

2. Part 2 involves the navigating through a maze on a computer monitor and the completion of a questionnaire about your experience doing the maze. All participants will get the opportunity to familiarize themselves with the computer simulation before doing the experimental task.

3. Part 3 involves a short debriefing session in which the participant gets the chance to describe his or her experience of interacting with the virtual environment.

IMPORTANT: You *may* experience some very mild disorientation when doing the maze task. Some people take a couple of minutes to get used to the real world after being immersed in a simulated computer environment. Such disorientation is not uncomfortable and is not likely to last beyond the time of the actual experiment.

What will happen to the information we gather?

The results of the project may be published in an academic journal or book, but you can be sure that all individual data collected during this study will remain confidential. Only averages for each experimental group will be reported. All information obtained from the study will be kept in locked cabinets and password-protected files. The identity of participants will not be made public without their consent.

If *you* would like to receive a summary of the findings, please contact Anne Hamarsnes.

Where and when will the study take place?

This study will take place between August and December 2005 in the experimental psychology lab in the School of Psychology, Massey University, Palmerston North. Each experimental session will take 50-60 minutes to complete.

Your Rights as a Participant

You are under no obligation to accept this invitation to participate in the present study. If you decide to participate, you have the right to:

- Decline to answer any particular question.
- Decline to take part in any task or procedure.
- Withdraw from the study.
- Ask any question about the study at any time during participation.
- Provide information on the understanding that your name will not be used unless you give permission to the researcher.
- Be given access to a summary of the study findings when it is concluded.

Ethical Approval

This project has been reviewed and approved by the Massey University Human Ethics Committee, Wellington Application 05/22. If you have any concerns about the conduct of this research, please contact Professor Sylvia Rumball, Chair, Massey University Campus Human Ethics Committee: WGTN telephone 06 350 5249, email humanethicswn@massey.ac.nz.

If you would like to participate in this study, please fill in your contact details on the following page and return it using the freepost envelope.

The effects of spatial ability on individual experiences of presence in first person and third person view virtual environments

YOUR CONTACT DETAILS

If you would like to participate in this study, which aims to explore the effects of spatial ability on the level of presence experienced in first person and third person environments, please complete this page and return it to the researchers using the **freepost envelope** (or drop it into the School of Psychology Office, Second Floor, Psychology Building, Palmerston North):

Name: ………………………………………………………………………………………

Phone number: …………………………………………………………………………..

Email address: …………………………………………………………………………...

Times at which it is best/most convenient to contact you: ………………………………...

………………………………………………………………………………………………

Remember: If at any stage you have any questions regarding this research, please feel free to contact me (Anne Hamarsnes) or Dr. Stephen Hill – please see the front page of the Information Sheet for our contact details.

This project has been reviewed and approved by the Massey University Human Ethics Committee, Wellington Application 05/22. If you have any concerns about the conduct of this research, please contact Professor Sylvia Rumball, Chair, Massey University Campus Human Ethics Committee: WGTN telephone 06 350 5249, email humanethicswn@massey.ac.nz.

Thank you for your interest in this study!

The Sense of Presence in Virtual Worlds

PARTICIPANT CONSENT FORM

This consent form will be held for a period of five (5) years.

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature:.. Date:..............

Full Name (in print):...

This project has been reviewed and approved by the Massey University Human Ethics Committee, Wellington Application 05/22. If you have any concerns about the conduct of this research, please contact Professor Sylvia Rumball, Chair, Massey University Campus Human Ethics Committee: WGTN telephone 06 350 5249, email humanethicswn@massey.ac.nz.

Appendix B

This appendix contains: Screening Questionnaire and MEC Spatial Presence Questionnaire (MEC-SPQ)

BACKGROUND

1. Are you right-handed or left-handed?

Right	Left

PREVIOUS EXPERIENCE

To be completed when participants turn up for the experiment.

1. How often do you play video/computer games (including massive multiplayer online games)? (*please tick one box as your answer*)

Every day for more than 2 hours

Every day for less than 2 hours

Once a week

Infrequently

Never

Comment:………………………………………………………………………
…………………………………………………………………………………………
…..

2. How often do you play video/computer games from a third person view perspective (i.e. as when you are manoeuvring an avatar/a visual representation of your "character")? *(please tick one box as your answer)*

Every day for more than 2 hours

Every day for less than 2 hours

Once a week

Infrequently

☐

Never

☐

Comment:……………………………………………………………………………………
……………………………………………………………………………………………
……..

3. **How often do you play video/computer games from a first person view perspective (i.e. as in first person shooter games where there is no avatar in your visual field)? (*please tick one box as your answer*)**

Every day for more than 2 hours

☐

Every day for less than 2 hours

☐

Once a week

☐

Infrequently

☐

Never

☐

Comment:……………………………………………………………………………………
……………………………………………………………………………………………
……..

4. **What type of video/computer games do you normally play?**

   Name(s):

   Type(s):

Comment:……………………………………………………………………………………
……………………………………………………………………………………………
……..

THE MEC SPATIAL PRESENCE QUESTIONNAIRE

(please circle one number as your answer)

1. When someone describes a space to me, it's usually very easy for me to imagine it clearly

1__________2__________3__________4__________5

I do not agree at all — I do fully agree

2. I thought intensely about the meaning of the VE presentation

1__________2__________3__________4__________5

I do not agree at all — I do fully agree

3. It seemed as though I actually took part in the action of the presentation

1__________2__________3__________4__________5

I do not agree at all — I do fully agree

4. I had the impression that I could act in the environment in the presentation

1__________2__________3__________4__________5

I do not agree at all — I do fully agree

5. I thought about just how much I know about the things in the presentation

1__________2__________3__________4__________5

I do not agree at all — I do fully agree

6. The VE captured my senses

1__________2__________3__________4__________5

I do not agree at all — I do fully agree

7. I was able to make a good estimate of how far apart things were from each other

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

8. I felt as though I was physically present in the environment of the presentation

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

9. I felt like I could move around among the objects in the presentation

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

10. The objects in the presentation gave me the feeling that I could do things with them

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

11. My attention was claimed by the VE

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

12. I had a precise idea of the spatial surroundings presented in the VE

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

13. When someone gives me directions to a place, I can picture the route as though I were watching a film

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

14. I thought about whether the VE presentation could be of use to me

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

15. When someone shows me a blueprint, I am able to imagine the space easily

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

16. I was able to imagine the arrangement of the spaces presented in the VE very well

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

17. It's easy for me to negotiate a space in my mind without actually being there

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

18. It seemed to me that I could have some effect on things in the presentation, as I do in real life

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

19. I didn't really pay attention to the existence of errors or inconsistencies in the VE

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

20. I thought most about things having to do with the VE

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

21. I had the impression that I could be active in the environment of the presentation

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

22. It seemed to me that I could do whatever I wanted in the environment of the presentation

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

23. **It was important for me to check whether inconsistencies were present in the VE**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

24. **I concentrated on whether there were any inconsistencies in the VE**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

25. **I was able to make a good estimate of the size of the presented space**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

26. **When I read a text, I can usually easily imagine the arrangement of the objects described**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

27. **The VE presentation activated my thinking**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

28. **I thoroughly considered what the things in the presentation had to do with one another**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

29. **I dedicated myself completely to the VE**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

30. **I directed my attention to possible errors or contradictions in the VE**

1__________2__________3__________4__________5

I do not agree at all   I do fully agree

31. **It was as though my true location had shifted into the environment in the presentation**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

32. **When a picture shows only part of a space, I can clearly imagine the rest of the space**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

33. **Even now, I could still find my way around the spatial environment in the presentation**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

34. **I took a critical view point of the VE presentation**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

35. **I concentrated on the VE**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

36. **I felt like the objects in the presentation surrounded me**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

37. **I felt like I was actually there in the environment of the presentation**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

38. **I devoted my whole attention to the VE**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

39. **I felt like I was part of the environment of the presentation**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

40. My perception focused on the VE almost automatically

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

41. Even now, I still have a concrete mental image of the spatial environment

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

42. It was not important for me whether the VE contained errors or contradictions

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

---

43. I am generally interested in the topic of the VE

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

44. The VE corresponded very well with what I normally prefer

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

45. I have felt a strong affinity to the theme of the VE for a long time

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

46. There was already a fondness in me for the topic of the VE before I was exposed to it

1___________2___________3___________4___________5

I do not agree at all | I do fully agree

47. **Things like the ones in the VE have often attracted my attention in the past**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

48. **I just love to think about the topic of the VE**

1___________2___________3___________4___________5

I do not agree at all — I do fully agree

Thank you very much for your participation!

Vorderer, P., Wirth, W., Gouveia, F. R., Biocca, F., Saari, T., Janke, F., Bocking, S., Schramm, H., Gysbergs, A., Hartmann, T., Klimmt, C., Laarni, J., Ravaja, N., Sacau, A., Baumgartner, T. & Janke, P. (2004). Mec Spatial Presence Questionnaire (MEC-SPQ): Short documentation and instructions for application. Report to the European Community, Project Presence: MEC (IST-2001-37661). Online. Available from http://www.ijk.hmt-hannover.de/presence.

Appendix C

This appendix contains: Complete Correlations Matrix

+ Amended versions of Table 3.1 and Table 3.2.

Table 5.6. Complete correlation matrix.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1Maze Time	-	.88**	-.31*	-.24*	-.53	-.05	-.23*	-.17	.02	-.22	-.28*	-.25*	-.18	.08	-.11	-.50**
2 Maze Error		-	-.18	-.14	-.4**	-.02	-.12	-.11	-.05	.01	-.2*	-.06	-.24*	.07	-.16	-.41**
3 MEC-SPQ			-	.79	.77	.79	.84	.75	.04	.63	.62	.24*	-.14	.11	-.07	.21
4 MEC AA				-	.59	.66	.63	.54	.04	.29*	.37*	.12	-.15	-.01	-.13	.19
5 MEC SSM					-	.42**	.54**	.49**	-.21	.49**	.70	.44**	-.11	.20	-.001	.39*
6 MEC SP						-	.79	.60	.01	.36*	.35*	-.01	-.1	.16	-.01	.05
7 MEC SPPA							-	.61	-.001	.49**	.36	.16	-.2	.15*	-.10*	.08
8 MEC HCI								-	-.003	.51	.33*	-.07	-.16	-.004	-.14	.03
9 MEC SoD									-	-.17	-.26*	-.26	-.06	.06	-.02	-.27*
10 MEC DSI										-	.38*	.32*	.01	-.03	-.01	.25
11 MEC VSI											-	.39*	.11	.13	.15	.28
12 MRT-A												-	.10	.26*	.20	.41**
13 OLMT(L)													-	.13	.89	.06
14 OLMT(M)														-	.57	-.12
15 OLMT(T)															-	-.001
16 Map Creation																-

** Correlation is significant at the 0.01 level
* Correlation is significant at the 0.05 level.

Table 3.1[1] Early definitions of spatial abilities.

Investigator	Factor Label	Factor Name	Factor Description	Tests
Guilford & Lacey (1947)	Vz	Visualisation	Ability to imagine the rotation of depicted objects, the folding or unfolding of flat patterns, the relative changes of position of objects in space	Vz: Pattern comprehension, mechanical comprehension
	SR	Spatial Relations	Relating different stimuli to different responses, arranged in spatial order	SR: Instrument comprehension, aerial orientation
Thurstine (1950)	S1		An ability to recognize the identity of an object when it is seen at different angles	S1: Flags, Card Rotation
	S2		An ability to visualize a configuration in which there is movement or displacement among the internal parts of the configuration	S2: Surface Development, Paper Puzzles
			An ability to think about those spatial relations in which the body orientation of the observer is an essential part of the problem	S3: Cube Comparisons
French (1951)	S	Space	Ability to perceive spatial patterns accurately and to compare them with each other	
	SO	Spatial Orientation	Ability to remain unconfused by the varying orientations in which a spatial pattern may be presented	
	V1		Ability to comprehend imaginary movement in three-dimensional space or the ability to manipulate objects in the imagination	
Michael, Zimmerman, & Guilford (1957)	SR-O	Spatial Relations and Orientation	Ability to comprehend the nature of the arrangement of elements within a visual stimulus pattern with respect to the examinee's body as a frame of reference	SR-O: Cubes, Flags, paper puzzles, aerial orientation
	Vz	Visualisation	Mental manipulation of a highly complex stimulus pattern	Vz: Form Board, directional plotting, pattern comprehension
French, Ekstrom, & Price (1963)	Vz	Visualisation	Ability to manipulate the stimulus and alter its image	Vz: Form Board, paperfolding, Surface
	S	Spatial Orientation	Perception of the position and configuration of objects in space with the observer as reference point	S: Card Rotations, Cube Comparisons

[1] This table is adapted from Flynn (1996, p.7).

Table 3.2[2] Some fundamental visuo-spatial abilities.

Ability	Description	Tests/measuring instruments
Visual organization	The ability to organize incomplete, not perfectly visible or fragmented patterns	Street Completion Test (Stree, 1931), Embedded Figures test (Witkin, Oltman, Raskin, & Karp, 1971), Hooper Visual Organisation test (Hooper, 1958), WAIS Object Assembly (Wechsler, 1944)
Planned visual scanning	The ability to scan a visual configuration rapidly and efficiently to reach a particular goal	Elithorn's Perceptual Maze test (Elithorn, Jones, Kerr & Lee, 1964), Trail-making test (Spreen & Strauss, 1991)
Spatial orientation	The ability to perceive and recall a particular spatial orientation or be able to orient oneself generally in space	Judgement of Line Orientation (Benton, Hamsher, Varney & Spreen, 1983)
Visual reconstructive ability	The ability to reconstruct a pattern (by drawing or using elements provided) on the basis of a given model	Koh's Blocks (see Block Design in the WAIS and WISC tests; Wechsler, 1945), Bender Gestalt test (Bender, 1938), Benton Visual Retention test (Benton, 1960), Complex Figure test (Rey, 1941)
Imagery generation ability	The ability to generate vivid visuo-spatial mental images quickly	VVIQ (Marks, 1972)
Imagery manipulation ability	The ability to manipulate a visuo-spatial mental image in order to transform or evaluate it	Mental Rotation test (Vandenberg & Kuse, 1978), Spatial Subtest of DAT (Bennett, Seahorse & Wesmann, 1954)
Spatial sequential short-term memory	The ability to remember a sequence of different locations	Corsi test (Milner, 1971), Tomal Subtests (Reynolds & Bigler, 1996)
Visuo-spatial simultaneous short-term memory	The ability to remember different locations presented simultaneously	Visual Pattern test (Della, Sala, Grey, Baddeley & Wilson, 1997)
Visual memory	The ability to remember visual information	Contribution of memory in the Complex Figure test (Rey, 1941)
Long-term spatial memory	The ability to maintain spatial information over long periods of time	Spatial Labyrinth (Milner, 1971)

VVIQ = Vividness of Visual Imagery Questionnaire

DAT = Differential Aptitude Test

[2] This table is adapted from Cornoldi & Vecchi (2003, p.16).